july, 1961

nlgi spokesman

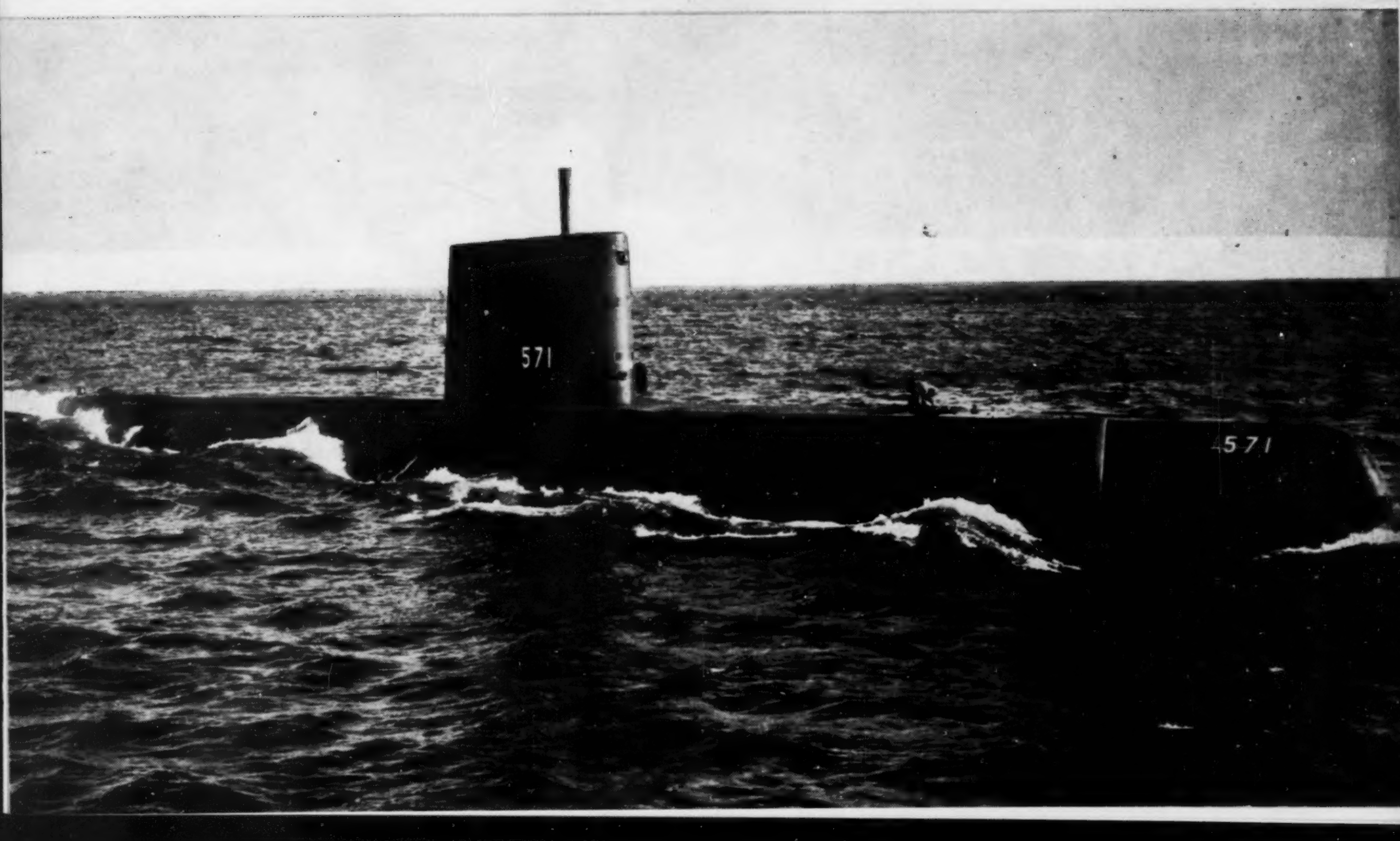
journal of the national lubricating grease institute

The Lubrication of Nuclear Power Plants

By R. S. BARNETT

Deleterious Particles and Wear

By L. C. BRUNSTRUM and K. R. BUNTING



nlgi spokesman

Volume XXV **July, 1961** **Number 4**

Published Monthly by the National Lubricating Grease Institute, T. W. H. MILLER, Editor; VIRGINIA ALLEN, Assistant Editor, 4638 J. C. Nichols Parkway, Kansas City 12, Missouri. Telephone VAlentine 1-6771. 1 Year Subscription, $5.00. 1 Year Subscription (Foreign), $6.00.

IN THIS ISSUE

THE COVER

NUCLEAR powered submarines are an accepted fact today, and an increasing number of them patrol under the seas in combat readiness, powered by their atomic reactors for long voyages in defense of the United States and its allies. What was once a surface boat which could submerge for short periods is now a true submersible, thanks to a source of power undreamed of a few years ago. There are a number of other uses for nuclear power, many of them peaceful, and lubrication can be of growing interest to the industry, as is touched on in *Lubrication of Nuclear Power Plants*, page 92.

Photo: United States Navy

NLGI PRESIDENT'S PAGE

By F. R. HART, *President*

Lubricants Proposed for Earthbound And Airborne Equipment in the Year 2000

The article that follows is the third in a series of four. Herein our forecaster talks about the lubricating greases needed for airborne, as well as earthbound equipment. Mr. E. O. Forster of Esso Research and Engineering Co. is giving this problem considerable thought as he feels it to be an extremely fascinating challenge.

Recent events confirm the necessity for developing lubricants capable of withstanding the pressures and temperatures of orbiting space vehicles. Now that man has been shot into space and safely returned to earth, it is reasonable to assume it will only be a few short years before interplanetary travel is an accepted fact. Coincident with the progress made in space travel, other research people are designing earthbound vehicles which, by comparison with present-day equipment, could be too fantastic in design to accept at this time. The automobile, as we know it today, may be replaced by helicopters and vehicles that travel on air cushions. These newer machines will need guiding instruments, air compressors, air purification systems and other auxiliary equipment requiring lubrication. Also, it should be recognized that transportation equipment will change drastically, possibly with greater reliance on high-speed air transport. Propeller-driven aircraft will be obsolete. Jets, ram jets and rocket-driven space vehicles will be in general use. Also, it is to be expected industrial machinery such as those units needed in the manufacture of goods, power generation, cargo movements, etc., will be equipped with bearings operating under conditions similar to but more severe than the present.

These mechanical developments call for a new concept of lubricants and their application. The main difference in lubrication requirements will be the environmental stresses; i.e., both higher and lower temperatures and pressures. Operation in high vacuum and over temperature extremes of —100° F. to +1,000° F. will be required for some machine elements in aircraft and space vehicles. These developments predict divergent trends. One involves the increasing use of wide-range multi-purpose greases for earthbound equipment to provide product simplicity and low maintenance cost. The other involves a growing need for specialty lubricants for use in airborne equipment. The products for this latter group will most likely be synthetic base or ultra-refined petroleum base greases. Nevertheless, soap-thickened petroleum base lubricants similar to those manufactured today, but of improved quality, will still dominate the market, particularly for earthbound machinery.

The forecast to be released next month stresses the effect of atomic radiation on the lubricants needed in future industrial machinery. This forecast comes from a Far Western research chemist and will prove interesting as it helps to consolidate the forecasts of the previous scientists. Look for it in the August issue.

Industry News

Because of its interest to the entire industry, a report on the activities of the American Society for Testing Materials, wherein they concern lubricating greases, is given below. These minutes consist of the report of Technical Committee G to ASTM Committee D-2 and of the reports of the active sections of Technical Committee G. They have been afforded NLGI by J. L. Dreher, secretary of Tech G.

Report of Technical Committee G On Lubricating Grease to ASTM Committee D-2 February 10, 1961

Technical Committee G met on February 7, 1961, with Mr. C. L. Pope presiding, and 37 members and guests in attendance.

The following actions by ASTM Committee D-2 were recommended:

1. *Reaffirm the following standards and tentatives*:

ASTM D 1261-55, Effect of Grease on Copper
ASTM D 1264-53T, Water Washout of Grease
ASTM D 1478-57T, Low Temperature Torque of Grease

The recommendation regarding the above two tentatives is based on pending minor modifications now under consideration.

2. *Establish ASTM D 1263-53T, Leakage of Automotive Grease, as a standard*, contingent upon letter ballot of Technical Committee G.

3. *Establish Roll Stability as a Tentative*, contingent upon letter ballot of Technical Committee G.

4. *Modify the sections of ASTM D 128-59, Standard Methods of Analysis*, pertaining to water determination by deleting Sections 22 to 27, inclusive, and replacing them with ASTM D 95, Water in Petroleum Products. The results of the letter ballot on this proposal were 40 yes, 4 not voting, and 1 no. The "no" vote cited as reasons that the proposal (1) eliminates the use of oleic acid needed as an antifoam agent in certain greases and (2) eliminates the use of xylol as a solvent, a superior solvent more available than petroleum distillate which is not carried by laboratory supply houses.

Other items of interest to Committee D-2 are as follows:

1. Joint symposium by Technical Committee G and NLGI on the "Effect of Oil Viscosity on Grease Characteristics" will be given as an all-day program at the 1961 NLGI meeting in Houston, Texas.

2. As a result of a questionnaire conducted by Technical Committee G on proposed new projects and revisions of present standards, Mr. Emmett Carmichael was appointed as chairman of a study group on methods of measuring extreme pressure and load carrying properties of greases. A report from the group at the June 1961 meeting is expected. Also, Mr. J. Lykins is chairman of a group formed to study methods of determining the effect of water and other fluid contaminants, such as rolling oils, on the consistency of grease.

3. The measurement of flow properties at low shear rates is being referred to the Fundamental Research Committee of NLGI for preliminary study.

4. Being guided by the definition established by NLGI, Mr. George Entwistle will prepare a definition of fillers as a preliminary step towards revising the section of ASTM D 128-59, Grease Analysis, pertaining to the determination of fillers.

Respectfully submitted,
J. L. Dreher
Secretary, Technical Committee G

Report of Section II to Technical Committee G February 7, 1961

This section has 8 methods under its control. Two, the *penetration* method and the *storage stability* method, were recently made tentative standards and need no attention at this time. Two others, the *dropping point* method and the new *roll stability* method, are under subcommittee investigation. The chairmen of these subsections held meetings yesterday and will report in some detail. I will comment on the other four as events have transpired since June.

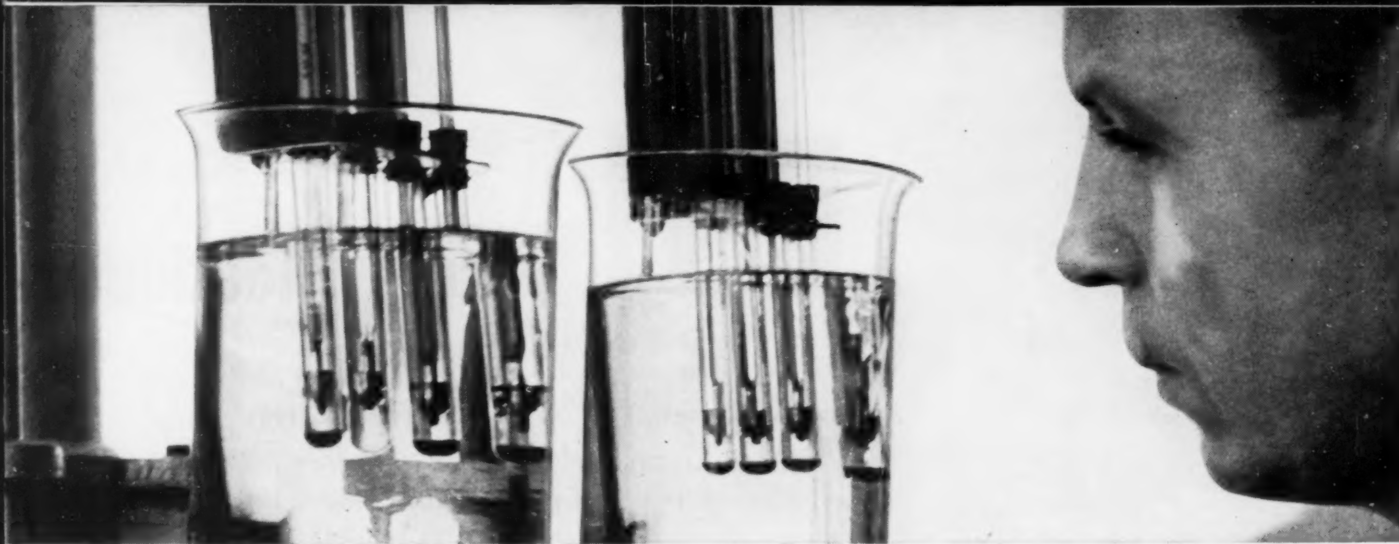
ASTM D 1092 Apparent Viscosity

No revision is indicated at this time, but extension to lower shear rates is necessary. Because some research may be necessary, either G-IV or NLGI-3 should consider this extension before Section II revises ASTM D 1092. Because G-IV has a program under way, it was decided to ask NLGI-3 to make the first attempt.

ASTM D 1404 Deleterious Particles

This method is not based on a correlation with service. Recently, American Oil Company attempted one such correlation. Six dummy fittings and collectors were fastened under a car and greased. After 1000 miles, half were wiped clean and regreased, half were left dirty and regreased. Grease from the clean fittings was clean under a microscope while the upwiped fittings yielded dirty grease. Both clean and dirty grease was submitted to the ASTM D 1404 test six times. Every time the clean grease resulted in a perfect plastic plate, the dirty grease scratched the plates. Two types of dirty grease so produced were then tested on a wear device in which thrust washers of 62 and 42 Rockwell hardness are used. Al-

Continued on page 114



Dropping point test shows how greases react to heat. Beaker fluid has been heated to 390°F. All greases tested except Darina (second tube from let) have passed from solid to liquid state.

BULLETIN:

Shell reveals the remarkable new component in Darina Grease that helps it save up to 35% on grease and labor costs

Darina® Grease is made with Microgel*, the new thickening agent developed by Shell Research.

Darina lubricates effectively at temperatures 100° hotter than most conventional soap base greases can withstand.

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Instead of soap, Darina uses Microgel—a grease component developed by Shell Research.

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Because of Microgel, Darina has no melting point. It won't run out of gears or bearings.

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Darina will withstand operating temperatures 100° hotter than most conventional multi-purpose greases. It cuts leakage and reduces the need for special high-temperature greases.

Also, Darina resists slumping, thus forming a more effective seal against foreign matter.

Saves money

Shell Darina can reduce maintenance expenses while it protects your machinery. Savings of up to 35% on grease and labor are quite possible.

In some cases lubrication intervals have been extended to double what they were before. Less grease is consumed and less time consumed applying it.

For details, see your Shell Representative. Or write: Shell Oil Company, 50 West 50th Street, New York 20, New York.

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SHELL

A BULLETIN FROM SHELL
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Tentative Program . . .

NLGI's 29th annual meeting

october 29— november 1, 1961 rice hotel houston, texas

Plans call for papers to be presented on these subjects:

- Planning the modern grease plant
- Building the modern grease plant
- Pilot scale manufacture of lubricating grease
- Rapeseed oil greases
- Marketing of special petroleum products
- New aspects in grease milling
- Complete survey of lubrication needs in the farm trade

and the ASTM-NLGI symposium on fluid gear lubricants . . . an all-day session in itself. Other papers will be announced at a later date.

Special programs for the ladies, not too far from Old Mexico, and the wonderful hospitality of the fabulous Texans can help add up to an annual meeting you won't want to miss.

Future Meetings

SEPTEMBER, 1961

11 NLGI Board of Directors meeting, Roosevelt Hotel, New York City.

13 API Division of Marketing, Lubrication Committee Meeting, Traymore Hotel, Atlantic City, N. J.

13-15 National Petroleum Association, Annual Meeting, Traymore Hotel, Atlantic City.

24-26 Independent Oil Compounders Association, Annual Meeting, Villa Moderne Motor Hotel, Highland Park, Ill.

24-28 ASTM Committee D-2 meeting, Statler Hotel, Detroit.

OCTOBER, 1961

17-19 ASME-ASLE Lubrication Conference, Hotel Morrison, Chicago.

18-20 Packaging Institute, 23rd Annual National Packaging Forum, Biltmore Hotel, New York City.

OCT. 29 - NOV. 1, 1961 NLGI Annual Meeting, Rice Hotel, Houston, Tex.

NOVEMBER, 1961

6-7 Petroleum Packaging Committee, Packaging Institute, Fort Shelby Hotel, Detroit, Mich.

9-10 SAE National Fuels and Lubricants Meeting, Shamrock-Hilton Hotel, Houston, Tex.

13-15 American Petroleum Institute Annual Meeting, Conrad Hilton Hotel, Chicago.

26-Dec. 1 ASME Winter Annual Meeting, Statler Hilton Hotel, New York.

JANUARY, 1962

8-12 Society of Automotive Engineers, Annual Meeting, Cobo Hall, Detroit, Mich.

FEBRUARY, 1962

21 NLGI Board of Directors meeting, Sheraton-Cadillac Hotel, Detroit, Mich.

MAY, 1962

22-25 API Division of Marketing, Midyear Meeting, Queen Elizabeth Hotel, Montreal, Canada.

OCTOBER, 1962

21-24 NLGI Annual Meeting, Edgewater Beach Hotel, Chicago, Ill.

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The Lubrication of Nuclear Power Plants

By: R. S. Barnett
Texaco Inc.

Presented at the NLGI 28th annual meeting in Chicago, October, 1960

WHAT HAPPENED at Hiroshima changed the world's conception of the atom from something very small to a symbol of destructive power. This paper deals with the origin, peaceful development and beneficial application of nuclear power, and with the many unusual problems including lubrication that are being solved. As an aid to full appreciation of these problems, the following concise review of atomic structure is advisable.

Energy-Mass Relationship

In 1905 Albert Einstein, the brilliant physicist and mathematician, conceived his theory that energy and mass were equivalent and wrote the deceptively simple equation

$$E = MC^2$$

which states that energy (E) is equal to mass (M) multiplied by the square of the velocity of light (C^2). Since light travels 186,000 miles in a second, C^2 is the very big number of 34,596,000,000—almost 35 billion. In other words Einstein's equation predicted that the atoms of even a small mass of matter contain a fantastic amount of energy: for example, one ounce of mass converted entirely into heat could change more than a million tons of water into steam.

In 1939 – thirty-four years later – Einstein's theory was proved by several scientists who discovered that the natural fissioning or splitting of "the" uranium atom (later identified specifically as uranium-235) converted some of its mass into energy.

Atomic Structure

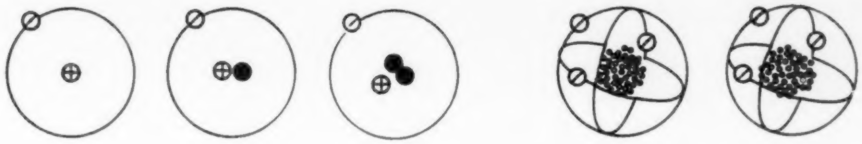
Recent measurements made with several different "atom smashing" equipments coupled with rather abstruse mathematics have enabled scientists not only to break apart and study the critical interior structure or nuclei of atoms but to artificially create new "man made" elements not previously identified in nature. These studies confirm that all stable atoms are composed of just three primary "building blocks" – protons, neutrons and electrons.

Protons and Neutrons

Various combinations of protons and neutrons form any atom's nucleus: though of similar size and extremely dense mass, the proton carries a positive (+) electrical charge while the neutron is electrically neutral. The mass number of an atom is the sum of its protons and neutrons.

Electrons

An electron is a particle about 1/1800th the size of a proton and carries an equal but negative (—) electrical charge: it is so tiny that more than 2½ trillion



MASS NUMBER (PROTONS + NEUTRONS)	1	2	3	235	238
ATOMIC OR ELEMENT NUMBER (PROTON - ELECTRON PAIRS)	1	1	1	92	92
ELEMENT	HYDROGEN	HYDROGEN	HYDROGEN	URANIUM	URANIUM
ISOTOPE NAMES	HYDROGEN-1 OR PROTONIUM	HYDROGEN-2 OR DEUTERIUM	HYDROGEN-3 OR TRITIUM	URANIUM-235	URANIUM-238
% NATURAL OCCURRENCE IN ELEMENT	99.98	0.02	0.0000000001	0.7	99.3
STABILITY	STABLE	STABLE	RADIOACTIVE	RADIOACTIVE	RADIOACTIVE
NUMBER OF PROTONS ⊕	1	1	1	92	92
NUMBER OF NEUTRONS ●	0	1	2	143	146
NUMBER OF ELECTRONS ⊘	1	1	1	92	92
NUMBER OF ELECTRON "SHELLS"	1	1	1	7	7

FIGURE 1—Atomic structure of the hydrogen and two uranium isotopes.

electrons laid end to end would occupy only one inch. An atom's exterior "shells" contain from one to as many as 102 electrons. In a stable inactive atom, each negative electron is electrically counterbalanced by a positive proton. The number of protons (or electrons) present in the atom is its atomic number which designates the elemental family to which the atom belongs and which is sometimes used instead of a written name. As examples, hydrogen is element No. 1 while uranium is element No. 92.

Isotopes

Originally it was believed that all the individual atoms in any quantity of elemental material like hydrogen were exactly alike: now it is certain that all but a few of the currently known 103 elements (11 of these being man-made) contain several different isotopes or "varieties" of the basic element and something over 1000 isotopes have been identified. In other words, an element can no longer be regarded as a single individual but instead is a family group composed of individual isotopes.

The isotopes of a given elemental family all have exactly the same number of electrons in their external atomic shells; consequently, they behave exactly alike during the formation of chemical compounds and, therefore, cannot be separated from each other by purely chemical methods. However, the nucleus of each isotope in an elemental family has its own distinctive number of neutrons and this number is simply the difference between its mass number and atomic number.

The lightest and simplest of all atoms are those three isotopes of the hydrogen family which are schematically diagrammed in Figure 1. For emphasis, similar diagrams for uranium-235 and uranium-238 (which are at the opposite heavy end of the atomic scale) are also shown; however, the veritable clouds of electrons around these huge complex uranium atoms cannot be pictured accurately. All five of the isotopes shown in Figure 1 occur naturally but, as the percentage figures indicate, some are exceedingly scarce. Fortunately, however, tritium and many other extremely useful isotopes can now be made readily with the aid of nuclear reactors.

Radioactivity

In 1896 Antoine Becquerel of France accidentally discovered that a piece of the heavy black uranium ore called pitchblende had mysteriously darkened a nearby unexposed photographic plate, apparently by giving off an emanation or radiation which passed through the protective cover on the plate. In 1898 Pierre and Marie Curie of France isolated a salt of the new element radium from pitchblende, determined that it was the principal source of Becquerel's mysterious radiation, and found that neither heat nor pressure would alter its steady rate of emanation. Thus, radium was the first naturally radioactive element to be discovered and scientists correctly concluded that its emanations came from deep within its atoms. In fact, this radiation is a form of energy produced by a change in mass or stepwise "decay" of the radium atom into other lighter isotopes and eventually into

common wholly-stable metallic lead. The life of a radioactive isotope may be as short as a few fleeting millionths of one second or as long as many millions of years. Since radiation is readily detected and measured by such instruments as the Geiger counter, radioactive isotopes (either natural but commonly artificial) used as "tracers" give scientists an invaluable new tool for applying radiation, for measuring mechanical changes, and for studying complex chemical reactions in petroleum[A], medical and agricultural research.

Chemical Versus Nuclear Reactions

Ordinary chemical reactions such as oxidation and reduction involve only the electrons of an atom: its nucleus is undisturbed, and the atom is therefore perpetually reusable. For example, when the carbon atoms in coal react (burn) with oxygen atoms in the air, they join together to make molecules of carbon dioxide, a gaseous chemical compound, and give off useful heat.[B]

$$C + O_2 \longrightarrow CO_2 + \text{heat}$$

Any green living plant is continually proving that this reaction is reversible and that the atoms in such a molecule are unchanged. Through a process called photosynthesis, the plant uses sunlight energy to take carbon dioxide molecules apart, reuses the carbon to build other molecules within itself and returns pure oxygen to the air.

On the other hand, anything which changes the nucleus of an atom also changes the entire nature of the atom, and the change is irreversible. Radioactivity, transmutation, fusion and fission all affect the nucleus and therefore change the original atom into something quite different.

Fissioning

As far back as 1914 the English physicist Ernest Rutherford had predicted: "It is possible that the nucleus of an atom may be altered by direct collision with very swift electrons or atoms of helium (alpha particles) such as are ejected from radioactive matter." Since that time a large number of different types of accelerators have been developed which can impart high velocities to a number of electrically charged particles (electrons, protons, deuterons, alpha particles, nuclei and positive ions of elements heavier than helium) and can use such projectiles to bombard and change the nuclei of many isotopes into others. These machines are inefficient in the power sense since they require the application of immense quantities of power to achieve a proportionally tiny reaction and are mostly impractical for anything but research. The resultant reactions also cease as soon as the external power is turned off, i.e., the reactions are not self-sustaining. These machines are handicapped by the fact that their electrically charged projectiles are easily deflected by either the protons or electrons of the "target" atoms, consequently, a low proportion of hits are made. In 1932 Sir James Chadwick discovered the electrically-neutral neutron which became the nuclear physicist's most effective projectile.

By bombarding various materials with neutrons, many new isotopes of various elements can be made, and many of these isotopes can be made radioactive. Certain atoms when they absorb neutrons may split into two or more parts with the simultaneous emission of additional neutrons, thus giving rise to a chain "fission" reaction. The atoms which can sustain such a chain fission reaction are uranium-235, plutonium-239 and uranium-233. Of these three, only uranium-235 is found in nature (0.7 per cent in bulk uranium), however, plutonium-239 and uranium-233 can be man-made in atomic piles from the fairly plentiful uranium-238 and thorium-232 respectively by causing each to absorb an additional neutron. As indicated by their mass numbers, these progeny are heavier than their parents and the process is termed a breeder reaction. The principal function of Oak Ridge was to separate and concentrate uranium-235 from bulk uranium.

If more than a minimum quantity (called the critical mass) of uranium-235 is merely brought together compactly, the mass immediately becomes "critical" and accelerated fission occurs, as diagrammed in Figure 2. Unless controls are provided, this reaction results in an atomic bomb detonation with its practically instantaneous evolution of huge quantities of heat and radiation. For the peaceful production of power, however, the same reaction is slowed down and controlled by means of control materials to give the desired steady controllable production of heat that is readily converted into industrial power. Control is achieved by inserting rods containing cadmium or boron into the critical mass, since these two elements absorb surplus neutrons. Control rods of solid hafnium are also used, as this metal has a high capacity for neutron capture and good structural and radiation-resistant properties. Neutrons ejected from any fissioning material are of the "fast" type which are not as effective in producing further fissioning as the "slow" or "thermal" type. Moderator materials such as water or graphite which have the property of slowing down fast neutrons to thermal neutrons without appreciably absorbing them are, therefore, inserted into the reactor.

The first "pile," using graphite and uranium with cadmium-coated steel control rods, was built in Chicago by Enrico Fermi and first sustained a controlled chain reaction on December 2, 1942.

Expanded versions of this same natural uranium-graphite reactor are being used to generate power and

A. Magazine, *Lubrication* Dec., 1955, "Application of Radioactive Tracers in the Petroleum Industry."

B. It has been calculated that a very tiny amount of mass is converted into energy during chemical combustion. The quantity of matter converted is too small to be weighed, being of the order of a few billionths of a gram per mole.

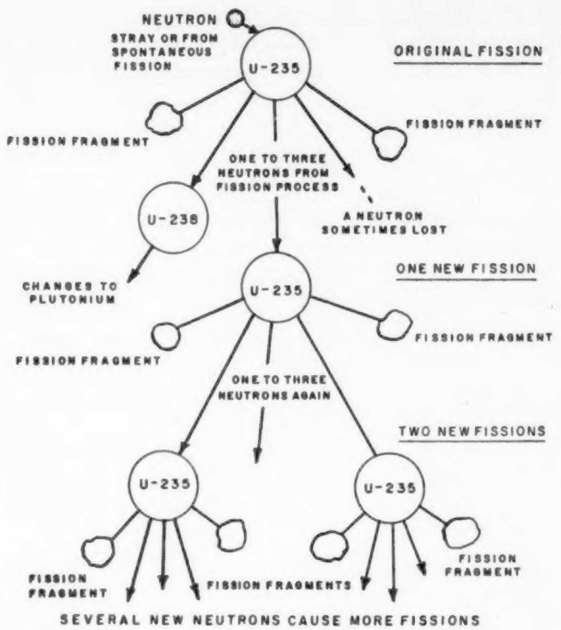


FIGURE 2—Schematic of the initiation and progress of "chain" fissioning of uranium-235.

produce plutonium-239. The use of enriched uranium (a mixture of U-238 and U-235 in which the proportion of the latter highly-fissionable material has been artificially increased) permits a reduction of pile size while maintaining power output.

There are many other reactor types which are under investigation, several of which are built in pilot model scale.

Fusion

Not satisfied with splitting the atom, scientists are now trying to achieve controlled atomic fusion. Life as we know it would not exist without atomic fusion, as this is the way that our sun produces sunlight: by a fusion reaction of hydrogen to helium at tremendously high temperatures. In this nuclear reaction, some mass is converted into energy. Hydrogen fusion has been achieved on earth in the hydrogen bomb which uses an A-bomb as a detonator to furnish the triggering heat.

Unlike fission, there are no long-lived radioactive, poisonous isotopes formed in the fusion reaction. Heavy hydrogen (deuterium), the preferred H isotope for fusion, can be obtained in unlimited supplies from sea water. The main problem is to produce and control the fantastically high temperatures (100,000,000°K) needed to initiate fusion.

Shielding

Not indicated in Figure 2 are several other products of the fission reaction such as emanations of alpha particles (helium nuclei), beta particles (electrons) and gamma type radiation which could affect surrounding personnel and materials. Alpha and beta particles and fission fragments have comparatively little penetrating power and are easily guarded against. Gamma radiation, however, has shorter wavelength and correspondingly higher penetration than X-rays: shielding of steel, metallic lead, massive sections of concrete and other materials is accordingly required to confine both gamma radiation and neutrons.

The shielding and safety aspects of present nuclear power reactors have been so well worked out that personnel are well protected, and selected conventional lubricants are satisfactory for the turbine and most auxiliary equipment bearings which are outside the shield. In most water-cooled reactors, water-circulating pumps and hydraulic control-rod actuators, which do get exposed to some radiation, are lubricated with water, which becomes only slightly and temporarily radioactive. Spent fuel elements are removed and handled under water which serves as a radiation shield. The reprocessing of spent fuel is a costly and complex chemical operation, and is one reason why nuclear plants are uneconomic at present.

Nuclear Power Plants

There are two general types of reactors, homogeneous and heterogeneous, and there are several sub types.

In homogeneous reactors, the fissionable material is dissolved or dispersed in a pumpable solution or slurry. This system has the advantage that fresh fuel can be pumped in easily while part of the old fluid charge can be drained off for reprocessing to remove accumulating waste products, which would otherwise absorb neutrons and thus "poison" the reaction. However, no large homogeneous reactors are operating because severe internal corrosion and other problems have not been overcome.

All the reactors to be described in the following are of the heterogeneous type in which the uranium or uranium compound is in shaped form, and usually enclosed or "clad" in corrosion- and heat-resistant metal tubes which are supported in a metal framework with intervening control rods. Figure 3 illustrates such an assembly (called a "core") together with its containing vessel.

The motion of the fission fragments is responsible for about 83 per cent of the total energy liberated in a fission reaction and this energy is quickly converted into sensible heat by the impact of these fragments on adjoining atoms. This heat must be removed both to prevent damage to the core and to permit its conversion into useful power.

Purified water is used as the moderator, coolant and heat transfer agent in leading United States designs of heterogeneous reactors. A Boiling Water Reactor (BWR) allows the water to boil directly into pres-

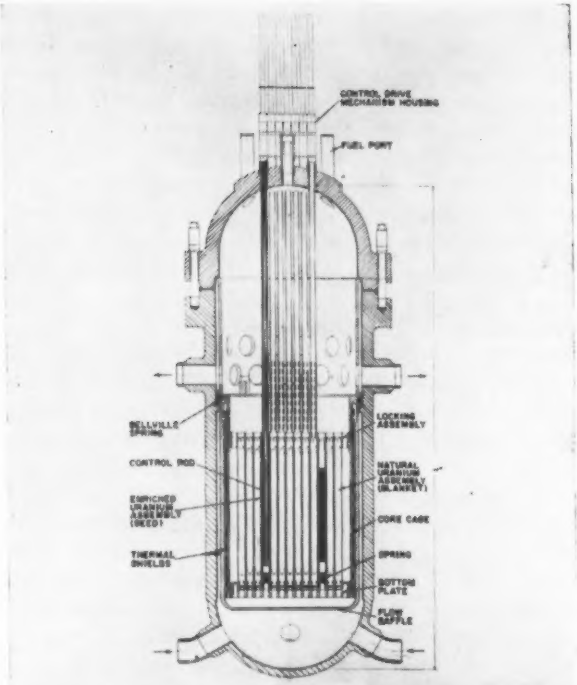


FIGURE 3—Core and pressure vessel of the Shippingport heterogeneous pressurized-water nuclear reactor. Height 33 ft.; inside diameter, 9 ft.; wall thickness, almost 9 inches including ¼-inch stainless steel lining; weight including uranium, more than 250 tons.

surized steam.[1,2] However, in the Pressurized Water Reactor (PWR) diagrammed in Figure 4, sufficient pressure is maintained to keep the reactor water in the fluid state and it is then circulated through heat exchangers which convert a secondary and separate supply of water into steam. When metallic uranium is used, reactor temperature must be kept low with the result that the steam produced has a temperature and pressure of only about 500°F and 600 psi. This temperature is quite modest when compared to the 1000°F or hotter steam being used in conventional oil or coal-fired power plants, and larger and more expensive steam turbines are therefore required to utilize it. Figure 5 presents a schematic comparison between conventional and nuclear steam power plants.

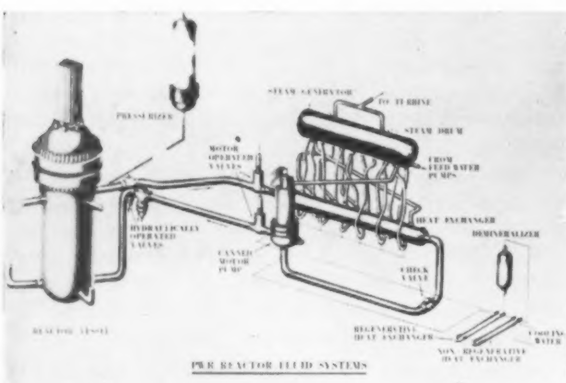


FIGURE 4—Schematic of heat exchanger system used with one pressurized water reactor.

The temperature problem is being solved by reactor cores composed of uranium dioxide pellets (in Zircaloy jackets) which withstand higher operating temperatures than metallic uranium.

Most nuclear reactors are designed to have a negative temperature coefficient of reactivity, that is, as the reactor temperature tends to rise, the coolant becomes less dense and does not moderate or slow down the neutrons as efficiently, thus causing a slowing down of the nuclear fission. Therefore, control-rod action is mainly necessary only for start-up, shutdown, or during large changes in power level.

As exemplified by England's Calder Hall reactors, an inert gas such as carbon dioxide may also be used as a coolant and heat-transfer agent. These large piles use natural uranium rods set in a graphite lattice moderator. Since the uranium fuel is not enriched, these piles must be of substantial size to obtain enough neutrons. By 1965 England expects to supply 20 to 25 per cent of its annual electric power requirements with gas-cooled reactors.

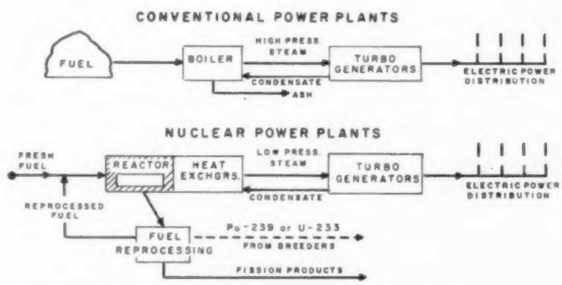


FIGURE 5—Schematic comparison between conventional and nuclear steam power plants.

The United States is implementing its Atoms for Peace program[4] by offering enriched uranium, "know-how," and components to the Euratom agency composed of France, Western Germany, Italy, Belgium, Netherlands and Luxembourg.

A recent paper at the Fifth World Petroleum Congress predicts that USA nuclear power will become competitive in high-cost fuel areas beginning about 1968. This may occur somewhat sooner in England because of its high population density, depleted coal resources and high oil imports.[5] A second paper given at the Congress points out that nuclear reactors may turn out to be most important as a source of process

heat, particularly if core radiation and that from fission fragments can be used to produce useful changes in material being processed.[6]

It was announced in May, 1960 that Southern California Edison had issued a letter of intent to Westinghouse Electric and Bechtel Corporation regarding a 360,000 KWe gross, pressurized water reactor. This would be the world's biggest reactor and may be competitive with fossil-fuel reactors in the production of electricity in the Los Angeles area.[7]

U. S. Army Packaged Power Reactor SM-1

Figure 6 pictures the exterior of the pilot model of this reactor which is located at Fort Belvoir, Va. Designed by Alco Products, Inc., it is one of the world's first nuclear plants built strictly for power generation. As indicated in Figure 7, it uses a pressurized water reactor with fully enriched uranium fuel and has a generating capacity of 1,855 kilowatts electrical. In

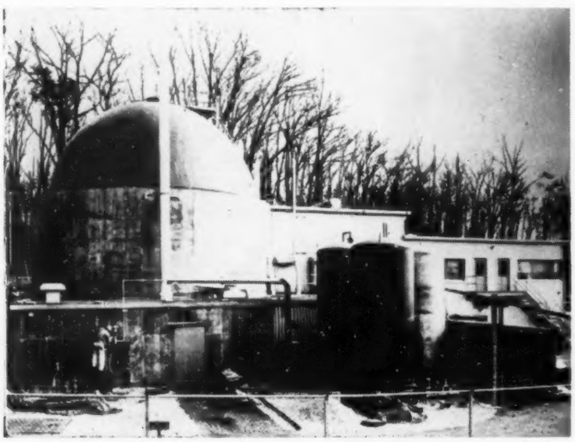


FIGURE 6—Exterior of first (pilot) model, U. S. Army Packaged Power Reactor.

operation since April, 1957, it has generated a total of 18,000,000 kilowatt-hours. Navy and Air Force operators are being trained, in addition to Army personnel, in this Defense Department project sponsored by the Atomic Energy Commission.

A second such plant of 4000 KWe, the SM-1A is now under construction at Fort Greely, Alaska. Details of nearly a year's operation of SM-1 (formerly designated the APPR-1) have been described.[8]

A recent review of the Army Nuclear Power Program gives the status of a number of reactors including those being built and those planned.[9] A portable plant PM-2A, based on the SM-1 design, is to be operational in the fall of 1960 at the sub-surface (under the ice) installation at Camp Century, Greenland. At 1,560 KWe, it will supply all electricity, one million BTU's/hour of steam for space heat and water treatment for this isolated facility.[9,10]

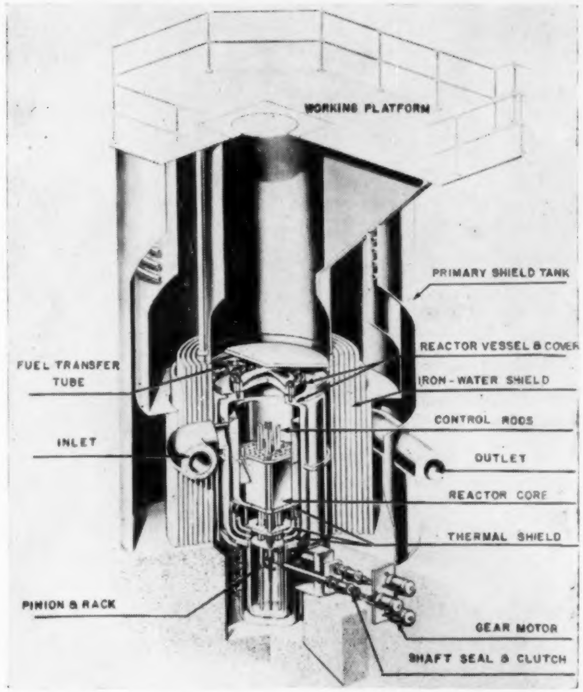


FIGURE 7—Isometric drawing of reactor vessel, core and control rod structure in the U. S. Army Packaged Power Reactor. Two additional safety control rods which are normally in fully withdrawn position are not shown.

Shippingport Plant

The first large-scale nuclear power plant in the United States went into operation in December, 1957, at Shippingport, Pa., near Pittsburgh. Sponsored by the Atomic Energy Commission, this 60,000 KWe plant was designed by Westinghouse and uses the pressurized water reactor shown in Figure 3. Operated by the Duquesne Light Co., the plant feeds its electrical output into the power system of that company. The reactor uses the so-called "seed-and-blanket" fuel concept which consists of seed cluster assemblies highly enriched in U-235 which give most of the initial power. The "blanket" part of the reactor is composed of natural uranium dioxide pellets, the U-238 portion of which is converted into plutonium-239 as the fissioning of the U-235 proceeds. The plutonium then fissions to give heat later in the life of the fuel charge.[11]

The Shippingport reactor generates steam at 600 psi through heat exchangers as diagrammed in Figure 4.

Dresden Power Plant

This plant, the first full-scale privately financed nuclear plant to go into operation in the United States, and among the largest in the world, has been built by the Commonwealth Edison Co., associated with the Nuclear Power Group Inc. (American Gas and Electric, Central Illinois Light, Illinois Power, Kansas City

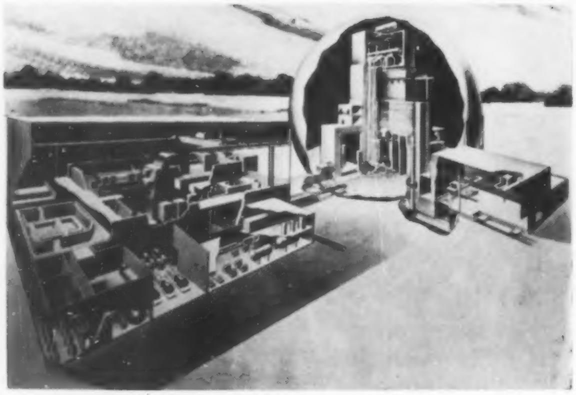


FIGURE 8—Reactor sphere, reactor fuel-handling section, turbogenerator and associated equipment of Dresden boiling-water nuclear reactor.

Power and Light, Pacific Gas and Electric, Union Electric Company of Missouri, and the Bechtel Corporation).

This plant is located at Morris, Ill., near Chicago, and will have a capacity of 180,000 kilowatts electrical.[1,2] It is using a dual cycle boiling water reactor designed by General Electric Co. and utilizes a slightly enriched uranium dioxide pellet core. The steam-water mixture produced in the reactor core flows to a primary steam drum where water and steam are separated. The steam flows to the turbine while the heated water is forced through the primary coils of a secondary steam generation system and then back to the reactor vessel. Primary steam is produced at 1000 psi and the secondary steam at 500 psi.

Figure 8 is a cutaway view of the sphere which contains the reactor and also shows the turbine and fuel-handling section. The plant "went critical" on October 15, 1959.

Indian Point Plant

The Consolidated Edison Co. of New York is building a 275,000 KWe plant at its own expense on the east bank of the Hudson at Indian Point,[12] N. Y., a few miles south of Peekskill. Figure 9 presents an artist's concept of the completed plant. This plant is a pressurized water type designed by Babcock and Wilcox and has two novel features.

The reactor will be a thorium converter in which thorium oxide will be mixed with fully enriched U-235 oxide and the mixture made into pellets. The UO_2 charge is valued at about $14,000,000 by the AEC. As the reaction proceeds, uranium-233 will be produced from the thorium and will in turn fission to produce heat in the later stages of the life of the fuel charge. Control rods will be made from solid hafnium for neutron absorption.

The plant will use a superheater heated by fuel oil to raise the steam temperature to 1000°F and thus make a more efficient plant.

Construction of this very large plant is well along and again indicates the financial commitment which American industry is making in nuclear plants with an eye towards the future. The plant is scheduled to "go critical" in 1961.

Enrico Fermi Fast Breeder Reactor

The Fermi Reactor[13] illustrated in Figure 10 and nearing completion on the shore of Lake Erie near Monroe, Mich., will use molten sodium as a coolant and heat transfer medium and enriched uranium alloy rods as fuel. The reactor is called "fast" because the neutrons are not slowed down as much as in the "thermal" reactors. The elements of the breeder blanket surrounding the core will be made of depleted uranium rods recovered from a previous core charge. It is believed that this reactor will produce more new fuel (in the form of plutonium-239) than it consumes.

Molten metal coolants, such as sodium, have significant advantages such as excellent heat-transfer properties, and ability to operate at high temperatures without the necessity for pressurizing the reactor (because of the high boiling point of sodium). Drawbacks are the violent reaction of sodium with any moisture, and

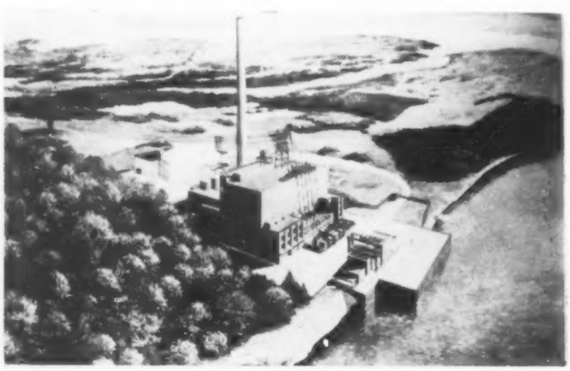


FIGURE 9—Indian Point pressurized-water breeder-reactor nuclear power plant.

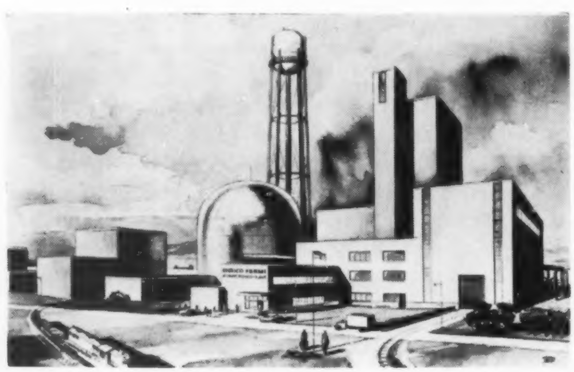


FIGURE 10—Enrico Fermi sodium-cooled fast breeder-reactor and power plant.

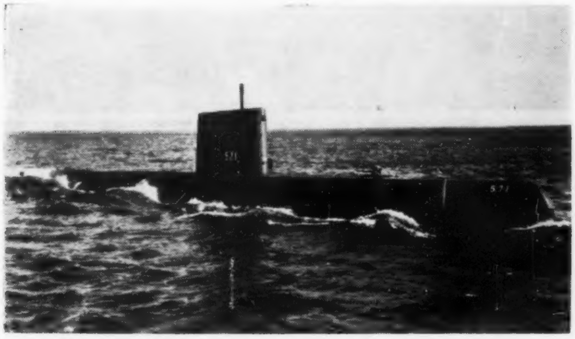


FIGURE 11—U. S. Submarine Nautilus.

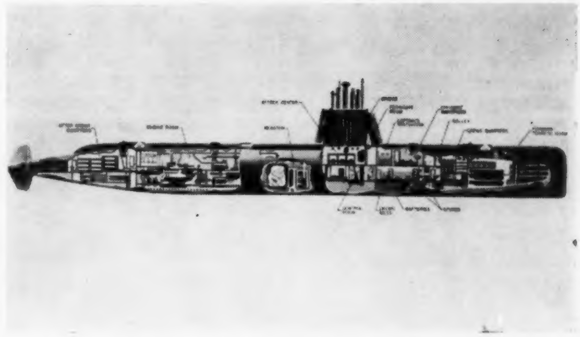


FIGURE 12—Schematic of interior, Submarine Nautilus.

the formation of highly radioactive sodium-24 by neutron capture. This latter factor will require considerable shielding of the heat exchanger equipment used to transfer heat from the sodium to water and steam.

The Enrico Fermi station will generate 100,000 KWe with steam at 740°F and 600 psi. Designed by Atomic Power Development Associates Inc., it is being constructed under the AEC Power Reactor Demonstration Program but predominantly financed by the Power Reactor Development Co., a non-profit organization of 23 companies. Power will be supplied to the Detroit Edison Co.'s distribution grid.

U. S. Submarine Nautilus

The most spectacular application of a nuclear reactor so far is considered to be that in the U. S. Navy Submarine Nautilus[14] illustrated in Figures 11 and 12 and subsequent submarines of the nuclear type.

The Nautilus was commissioned on September 30, 1954 and cast off on her maiden voyage on January 17, 1955. This epoch-making voyage opened up a completely new field of naval operations by demonstrating that a nuclear submarine could travel completely submerged for long periods of time. In fact, the Nautilus cruised for two years on its first nuclear fuel charge, and covered 62,560 miles of which 34,498 miles were submerged.

Another record-breaking achievement was the cruise of the Nautilus under polar ice in August, 1958. This charted a new route from the Pacific to the Atlantic, traveling from Hawaii to Europe in 19 days. The Nautilus nosed under the Arctic ice near Port Barrow on the north coast of Alaska on August 1; four days and 1830 miles later, this pioneering submarine surfaced near Greenland.

The Nautilus was built by General Dynamics Corp. (Electric Boat Division) and the reactor was designed by Westinghouse Electric Company.

Details of the Nautilus reactor are not known except that it is a pressurized water type using highly enriched uranium as the fuel. A number of additional nuclear-powered United States submarines are now cruising. The U. S. Navy will have at least 30 "A-Subs" when those under construction are finished, and contracts have been awarded for additional vessels.

N. S. Savannah

The first nuclear-powered merchant ship is the N. S. Savannah[15,16] now being completed at Camden, N. J., by the New York Shipbuilding Corp. under joint sponsorship of the AEC and the U. S. Maritime Administration. Pictured in Figure 13, the Savannah is of the dry cargo type with accommodations for 60 passengers and a crew of 109 and will be operated by the States Marine Lines Inc. Its reactor shown in Figure 14, was designed by Babcock and Wilcox and is of the heat-exchanger pressurized-water type to make 480 psi steam at 467°F. This 596-ft. ship of 22,000 tons displacement will cruise at 21 knots with its 20,000 shaft horsepower. The $42,500,000 vessel was launched July 21, 1959 and should be cruising under test in 1961. The N. S. Savannah will be used as a "floating laboratory" with a program of testing new designs of components.

The great interest in merchant ship propulsion is pointed up by the April, 1960 Atomic Industrial Forum Conference[17] where reactor designs were critically examined and the need for lighter, smaller and cheaper plants was emphasized to reduce capital costs. The

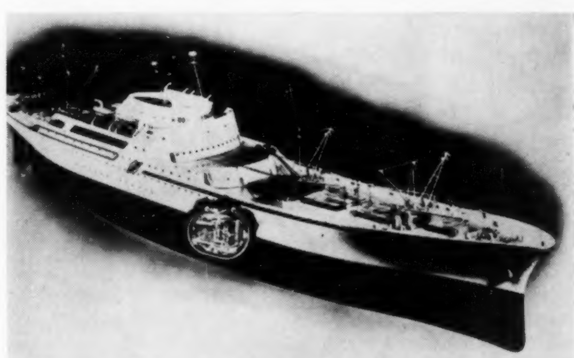


FIGURE 13—Artist's drawing of the N.S. (Nuclear Ship) Savannah with insert showing approximate location of its pressurized-water type nuclear reactor.

combination of a 30 knot nuclear superliner for the Pacific, with automated controls to reduce crew costs, appears promising.

Communication between marine and nuclear tech-

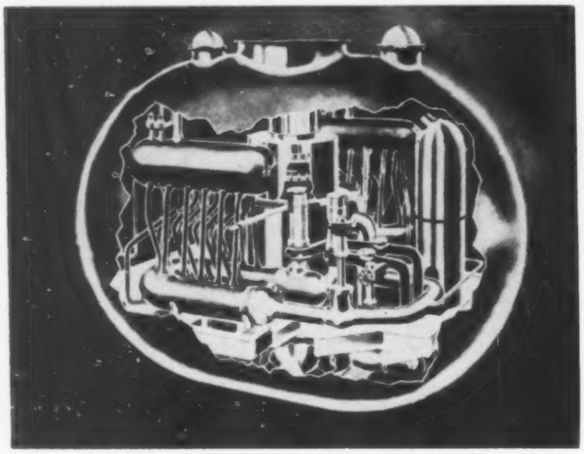


FIGURE 14—Schema of the Savannah's reactor, heat exchange equipment and enclosure.

nologists should be made easier by the appearance of a comprehensive new book on Nuclear Ship Propulsion written in the composite language "nuclear-marine."[18]

Radiation Studies in Petroleum Research

The extent of the investigation of the benefits to be derived from radiation by the petroleum industry is exemplified by the following descriptions of available laboratory equipment.

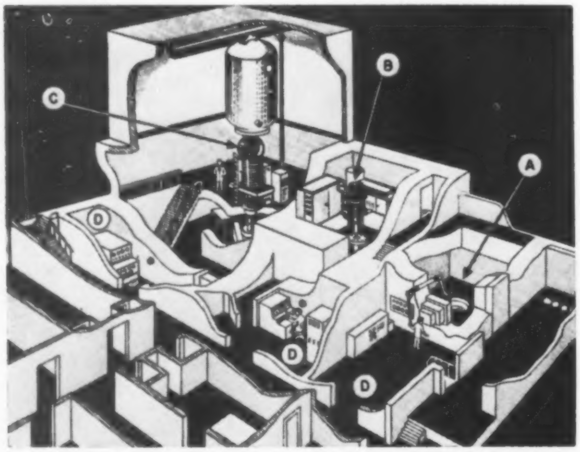


FIGURE 15—Schematic drawing of radiation laboratory building showing locations of principal equipment and the massive shielding required.

In 1958, the largest amount in petroleum research of radioactive cobalt-60 was installed in the "hot cell" of a new million dollar radiation laboratory designed and built especially by a prominent petroleum com-

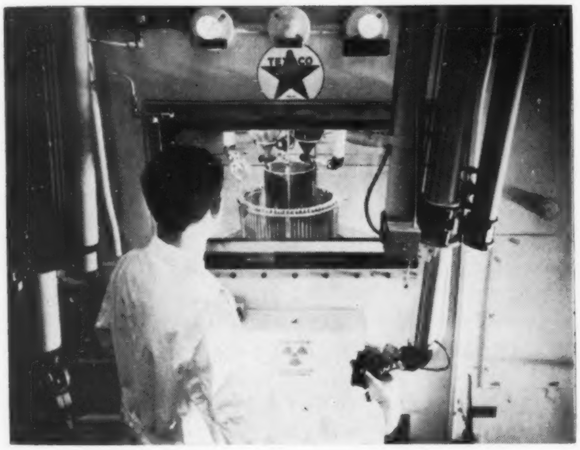


FIGURE 16—View from outside of hot cell through 42-inch-thick special safety window showing the large cobalt-60 source of gamma radiation in raised position. Operator is using one remote manipulator to adjust a stop cock.

pany to further expand its research with radioactivity.[19]

Schematic Figure 15 illustrates the unusual construction and heavy shielding of this laboratory, while the superimposed letters indicate its principal equipment as follows:

A. Cobalt-60 "Hot Cell"
B. Electron Linear Accelerator
C. Van de Graaff Proton Generator
D. Control Stations

Cobalt-60 "Hot Cell"

The gamma radiation emitted by the amount of cobalt-60 in this cell when installed was 29,100 curies, the equivalent of about 64 pounds of pure radium. Figure 16 taken from outside the heavily-shielded cell and through its 42-inch thick special window shows

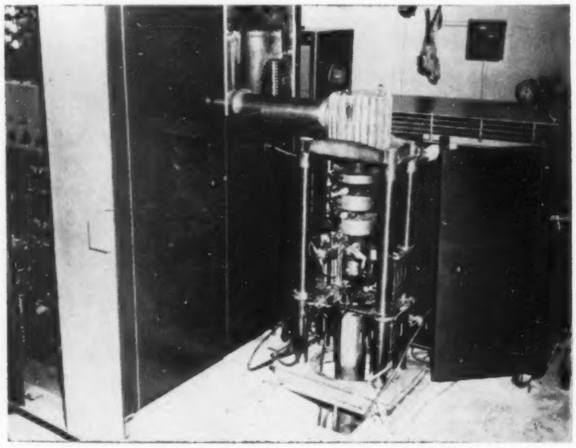


FIGURE 17—Generating portion (in upper room) of electron linear accelerator.

the ring of stainless steel "pencils" containing the cobalt-60 and surrounding a petroleum process apparatus. The arrangement and number of the cobalt-60 pencils can be varied to obtain desired intensities of gamma radiation, and other apparatus can also be adjusted by means of the two remote-control manipulators. The cobalt-60 rests on an elevator which is lowered into a deep well of water whenever anyone must enter the hot cell. Gamma radiation is so penetrating that it easily passes through the heavy steel vessels and heating jackets that are frequently employed in petroleum laboratory equipment. Thus the temperature, pressure and flow used in full scale refining processes can be duplicated in such laboratory equipment while subjecting the whole to gamma radiation.

FIGURE 18—Electron discharge tube and sample exposure table in lower room of electron linear accelerator.

Electron Linear Accelerator

Figure 17 shows the generating portion of the Electron Linear Accelerator power source and a Klystron tube located in the upper room which accelerate a concentrated beam of electrons (or beta radiation) to a speed more than nine-tenths the speed of light. Figure 18 illustrates placement of a laboratory sample under the electron discharge tube. The perforated motor-driven rotary table provides a convenient method for exposing many samples to the electron beam for precise intervals. Figure 19 shows the external control panel. This apparatus permits the concentration of a large amount of energy (in the high speed electrons) on a small sample. Since electrons have but little penetrating power, the sample must either be placed in a thin wall container or exposed directly. However, when electrons from this accelerator strike metals, highly penetrating X-rays are created, thus necessitating the heavy shielding around the instrument that is shown in Figure 15.

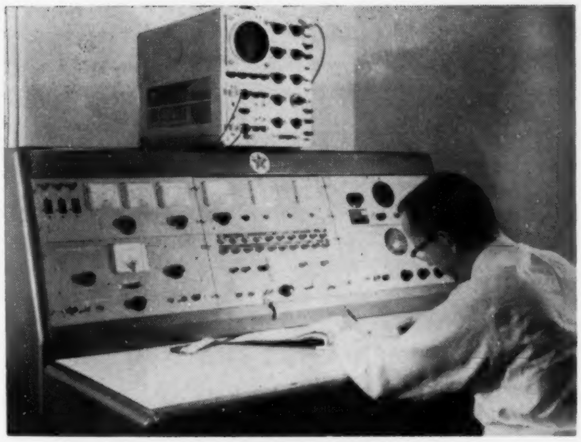


FIGURE 19—Electron linear accelerator control panel.

Van de Graaff Proton Generator

The right hand part of Figure 20 shows the upper or generating portion of the Van de Graaff generator with its heavy pressure tank temporarily removed and being placed at the reader's left. The instrument generates and uses three million volts to accelerate the protons or "positive ions" of hydrogen-2 (deuterium) nuclei and impinges them on a "target" of metallic beryllium which in turn releases neutrons. Figure 21 shows the tube containing the proton stream emerging from the ceiling into a large electromagnet which turns the stream horizontally and focuses it. The large block of material in the foreground is paraffin wax which surrounds the sample under study and acts as a moderator to convert the fast neutrons to the slow thermal type. Thus, the Van de Graaff is useful as an atom splitter to make minute quantities of radioactive isotopes and is the only one of the three instruments described which can modify atomic nuclei.

Other rooms included in the new radiation laboratory are a "hot lab" where radioactive materials can be handled, two organic chemical laboratories, a tracer lab and an analytical laboratory. The walls surrounding the radiation sources vary in thickness from 3½ to 7 feet.

By means of these new tools, the research scientists of this petroleum research organization are continuing their studies of the rearrangement of molecules in a way which is not possible with usual energy sources which (unlike radiation) cause severe heating as the material is being treated. Pertinent dosages of radiation energy can be used to bring about reactions which are not possible by any other means known today. For instance, it has been shown by a prominent electrical equipment manufacturer[20] that polyethylene can be

FIGURE 20—Generating portion (in upper room) of Van de Graaff three-million-volt proton generator.

made to resist melting by irradiation with electron beta rays and thereby increase its excellent electrical insulating properties. This radiation-modified plastic is now being used to insulate wires in electric motors which must run at high temperatures. A further development in irradiated polyethylene technology is the development of a shrinkable film for packaging food.[21]

What Radiation Does to Petroleum Products

Radiation changes petroleum (and also living plants and animals) in several ways, the amount and type of change depending upon the amount and type of radiation. Atoms become excited (made more reactive) by exposure to radiation and this effect leads to such chemical changes as breakage of chemical bonds and also the formation of free radicals.

The effects of radiation are generally cumulative: i.e. a short exposure to intensive radiation will produce the same effects as a longer exposure does to weaker radiation of the same type. Total dosage rather than dosage rate is the most important.

A unit called the "rad"[C] is the most practical measure of radiant energy since it can be used regardless of the type or mixtures of types of energy that are involved. However, for gamma and X-ray type radiations only, the more common unit is the roentgen.[D] For gamma radiation one rad is roughly equivalent to 1.2 roentgens.

C. The absorption of 100 ergs of energy by one gram of material.

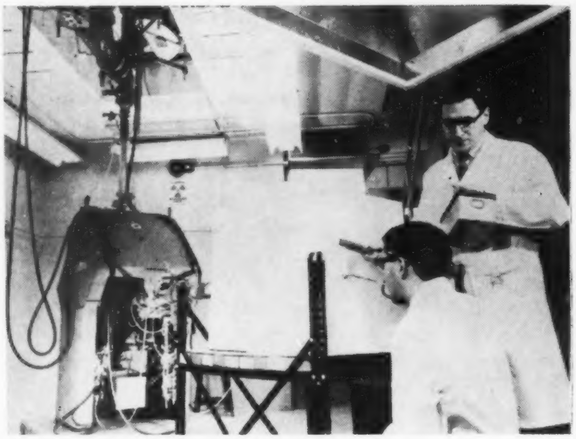


FIGURE 21—Operators (in lower room) checking radioactivity of wax-enclosed sample after exposure to neutron beam from Van de Graaff generator.

Alpha and Beta Particles

Near a nuclear reactor, petroleum products are not apt to be exposed to alpha and beta particles because of the low penetrating power of these forms of nuclear emissions which do not get through the primary shielding. However, the high energies of these particles would be extremely damaging to fuels and lubricants at short ranges because they ionize and dissociate the molecules causing changes in composition.

Gamma Radiation

Gamma rays are electromagnetic waves like X-rays, but of shorter wavelength and higher energy. Gamma rays originate in the nucleus of an unstable atom whereas X-rays come from the inner excited electron shell. On the other hand gamma rays of moderate intensity generally interact only with an atom's electron shells to cause ionization for example, but they do not affect its nucleus and therefore do not make it radioactive.

Fuels and lubricants become more reactive and change chemically with the absorption of gamma radiation: oxidation, evolution of gas and viscosity changes are accelerated. General levels of gamma radiation damage are as follows:

Total Dosage in Roentgens	*Effect*
200 to 800	lethal to humans
less than 5 million	generally negligible to oils and greases
5 million to 10 billion	organic fluids and greases are sensitive in this range
above 10 billion	only the most resistant organic structures survive

D. Gamma or X-ray radiation required to impart 83.8 ergs of energy to one gram of dry air.

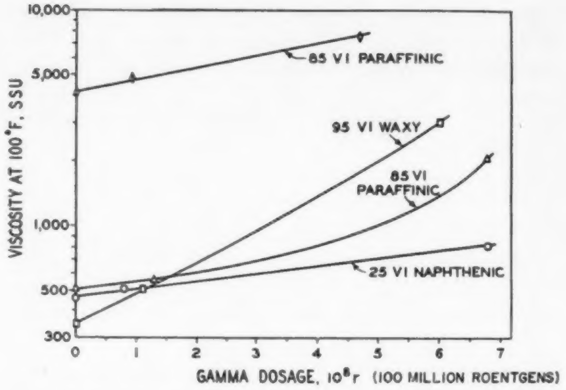


FIGURE 22—Viscosity change of base oils with irradiation.

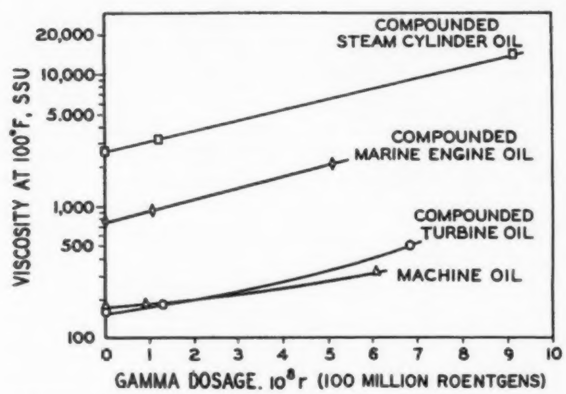


FIGURE 23—Viscosity change of industrial oils with irradiation.

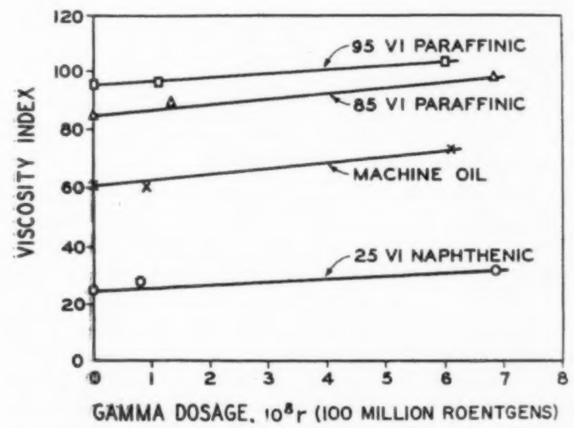


FIGURE 24—Effect of irradiation on viscosity index.

Neutron Exposure

In addition to the changes brought about by other forms of radiation, neutrons can change organics in two ways: (1) fast neutrons collide with hydrogen nuclei, ejecting fast "recoil" protons which induce secondary ionization and (2) thermal neutrons are captured by the nuclei which then decay and emit charged particles and gamma radiation. The exposed material also becomes heated during these changes as the kinetic energy of the atoms is increased.

From a damage standpoint, one rad of neutrons causes ten times more biological damage to living tissue than one rad of gamma radiation. For petroleum, the effects of these two radiation types are more nearly equivalent if some criterion such as viscosity increase is used as a measurement. On an energy deposit basis, neutrons may not do more damage than gamma radiation; however, it should be noted that such a comparison neglects the residual radioactivity that may be induced by neutron radiation.

Effects of Radiation on Oils

It has been reported[22] that gamma radiation of 100 to 900 million roentgens caused mineral oils and additive oils with mineral oil base to darken and acquire an acrid, oxidized odor; however, neutralization number increases were less than 0.5 and no sludge was evident. The evolution of gas in the form of hydrogen and light hydrocarbons also occurs and this may present a problem with sealed containers.

The curves of Figures 22, 23 and 24 indicate a general steady increase in viscosity and viscosity index with increasing gamma dosage. On the other hand, Figure 25 indicates that an automatic transmission fluid which contains a viscosity index improver may behave quite differently. The initial decrease in viscosity was probably due to breakdown of the polymer-type viscosity index improver which effect was finally overbalanced by the thickening of the base oil.

Gamma radiation actually improved the anti-wear characteristics of the above oils as measured by Almen (bronze-steel specimens) and Falex (steel-steel speci-

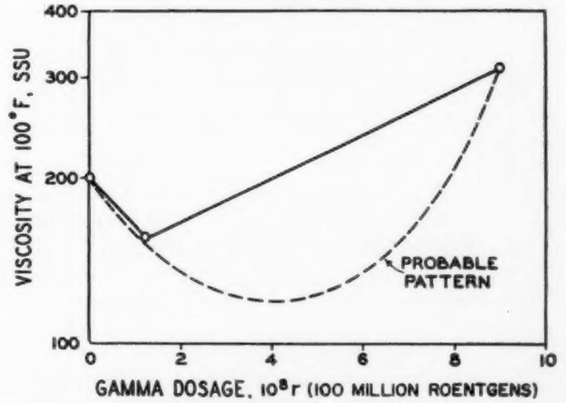


FIGURE 25—Radiation damage to a VI-improved automatic transmission fluid.

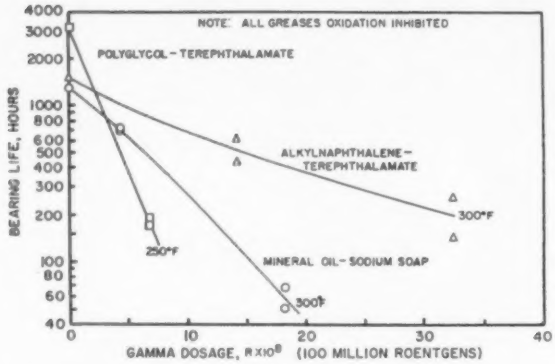


FIGURE 26—Effect of radiation on bearing life.

mens) tests. However, a MIL-L-2105 gear oil with its chlorine-containing additive also became very corrosive and gave off hydrochloric acid.

Effects of Radiation on Greases

Experimental work[23] has shown that greases generally first soften on irradiation because of disintegration of the soap structure, then finally become porous and brittle due to polymerization and crosslinking of the oil molecules. Performance life in bearings is reduced and oxidation resistance is impaired. Low temperature torque is impaired only to a minor degree at about 500 million roentgens but increases for higher dosages, whereas copper corrosivity, evaporation and brass-steel gear wear are not greatly increased. Greases made from alkyl-aromatic fluids (benzene or naphthalene derivatives) and gelled with sodium terephthalamate or a treated silica are the most radiation resistant according to this study. Figure 26 shows the effect of gamma radiation on the life of ball bearings lubricated with a terephthalamate synthetic grease versus a conventional sodium soap mineral oil grease.

Recent papers in British journals[24,25] present valuable information on lubricants for use in gas-cooled graphite-moderated reactors. Radiation-resistant greases are commercially available, and these are replacing the previously used bonded solid films of molybdenum disulfide which were unsatisfactory as regards durability and moisture corrosion. Gas-blower oils of very low vapor pressure have been developed to avoid contamination of the gas.

A recent paper[26] presents irradiation and thermal stability data on the meta-linked polyphenyl ethers as base fluids which show capabilities of use to 800-900°F and 10^9 rads. This paper also gives data on solid-film lubricants and radiation-resistant greases.

Effects of Radiation on Petroleum Fuels

The military services are interested in the effect of nuclear radiations on supplies of petroleum fuels as well as on other petroleum stocks. A review[27] presented in 1957 gives rather comprehensive findings on a gasoline stock, kerosine, stove oil, JP-3, JP-4 and JP-5 jet fuels. Gamma radiation up to five billion roentgens, and also exposure to one billion billion neutrons/cm^2 from a nuclear pile were used. (An approximate relationship for damage from neutrons in this case versus damage from gammas, based on viscosity change only, is that 10^{18} slow neutrons/cm^2 correspond to damage inflicted by one billion 300 million roentgens.)

The following conclusions were made, basis this work.

1. The weight per cent of hydrogen decreases and density increases during irradiation.
2. Radiation above 100 million roentgens gamma dosage drastically changes the physical properties of fuels. Materials of both higher and lower molecular weight than the original are formed.
3. Gas is evolved during irradiation. The quantity may be as high as 20 volumes of gas per volume of fuel at 500 million roentgens and increases approximately linearly.
4. Radiation causes viscosity increases, although this is not appreciable below about 500 million roentgens.
5. Olefin type hydrocarbons appeared to increase appreciably during irradiation, although present methods do not permit a quantitative assessment of this change.

Lubrication Problems in Nuclear Power Plants

Water-Cooled Reactors

As described earlier in this article, water-cooled and water-moderated reactors dominate the American scene. Most of these plants use water for the lubrication of critical bearings, for example, graphoid bearings of "canned" pumps.

A leading electrical equipment company has thoroughly studied the lubrication aspects of a nuclear power reactor of the boiling water type, based on a 12,500 kilowatt plant.[3] The following conclusions, basis adequate shielding, stable turbine oils and suitable relubrication periods were made:

"The over-all lubrication problems in a nuclear power plant will be very similar to those encountered in conventional steam power generating stations. Thermal and oxidative degradation conditions will be similar for petroleum lubricants in the two types of stations. The same general types of oils and greases will be employed, the relubrication schedules and inspection periods will be similar in length, and only minor attention must be paid to the possibility of the build-up of radioactive contaminants in the oil. The problems will vary only slightly with the type of nuclear power plant system employed since there will be the same general types of equipment to be lubricated and the radiation shielding will be similarly arranged for ready maintenance of the equipment."

Table I gives the calculated dosage levels at various

TABLE I

Radiation Effects on Lubricant Life in a Particular Nuclear Power Plant

Components	*Operating Dosage Level, Rads/Hr.*	*Lubricant Life (Hours to attain 100 milion Rads Exposure)*
Turbine	0.2	1 billion
Water Circulating Pumps	100	1 million
Remote Fuel Handling Devices	100,000	1000
Control Drive Mechanisms	100,000	1000
At Reactor Vessel Wall	1 million	100
At Reactor Core Center	10,000 billion	$\frac{1}{100,000}$

points in this 12,500 KW boiling-water power plant and shows how lubricant life is affected. As the turbine oil is exposed only to slight gamma radiation of about 0.24 roentgens (0.2 rads) per hour from the slightly radioactive steam, it does not itself become radioactive, and the used oil in this case could be handled in the same fashion as any other used turbine oil. It may be expected that radiation intensity decreases tremendously with distance from the reactor core. The radiation levels quoted in Table I are for a particular small plant and the reader is cautioned that larger plants or those of different design may well have quite different radiation levels at the various points in the system.

Oils containing metallic additives such as sodium, or metallic contamination, will become radioactive to a greater degree than straight mineral oils or those containing phosphorus and/or sulfur additives if exposed to neutron bombardment. Here again the question of whether such oils will become dangerously radioactive depends upon how close they are to the nuclear core where the fission reaction is taking place. The conventional 150 SUS viscosity turbine oil used as an example (such an oil would not be used inside the reactor shield) requires one billion hours to accumulate 120 million roentgens (100 million rads) of radiation dosage which is the approximate dosage level at which the oil begins to thicken excessively. This is because the turbine is so well shielded and so far removed from the "hot" core that the operating dosage level is very low for the design in question. Basis operating experience at the plants discussed earlier in this article, selected conventional lubricants are satisfactory for all points not lubricated by water in water-moderated plants. However, certain chlorine-containing lubricants will give off corrosive hydrochloric acid in the dosage range of 10 million to 50 million rads of gamma radiation.

Lubricants other than turbine oils will be those for the coolant circulation pumps, and for remote fuel handling and control rod mechanisms.

Gas-Cooled Reactors

A very recent article[24] describes the lubrication requirements of United Kingdom plants of the graphite-moderated carbon-dioxide-cooled type. Applications where specially formulated products are needed include fuel charge and discharge machines, reactor servicing machine, and control rod mechanisms. Fuel elements must be changed during full operation at about 200°C (392°F) to 400°C (752°F), in the presence of neutrons and gamma rays, and of hot carbon dioxide under pressure of about 150 psi.

Nuclear Powered Surface Vessels

A comprehensive study of the lubrication requirement of nuclear powered surface vessels was presented at the 15th Annual Meeting of the American Society of Lubrication Engineers.[28] This study was made for the U. S. Maritime Administration, and much of it is directly applicable to stationary nuclear power plants.

A wide range of reactor types are considered, and the following summary from the abstract of the paper gives the essential conclusions:

> "This review has indicated that the lubrication problems of nuclear propelled ships are similar to those of their conventional fossil-fueled counterparts. Radiation stress, the main new environmental feature, is a consideration only in those components which are associated with the nuclear heat source (control rods, etc.), and then it is generally not a controlling consideration. The lubricants for the propulsion gear and its auxiliary systems present no new lubrication problems. However, leakage and primary coolant contamination requirements often take precedence in the selection of the lubricant or lubrication system."

Effects of Radiation on Human Beings

The maximum permissible dosage for workers is usually given as only 0.3 roentgens per week for those over 18 years of age (younger persons should not be employed for nuclear radiation work because of genetic considerations). The maximum permissible yearly dose is 5 roentgens, which averages 0.1 roentgen for a 50-week work year.

Table I shows that the radiation intensity around the turbine of the 12,500 KW reactor is 0.2 rads per hour of gamma energy which is equivalent to 0.24 roentgens per hour. Therefore, a man working around the tur-

bine while the nuclear fission reaction is occurring would receive his maximum weekly dose in approximately one hour. However, when the reactor is closed down (i.e. made "sub-critical") the radiation from the radioactive steam or condensed water in the turbine dies out rapidly. Therefore, after a wait of only a few moments, the over-all radiation level is low enough so that it would not interfere with maintenance operations on the turbine itself. This estimate, of course, is based upon the particular type, size and power rating of the reactor described in Table I.

Summary

The petroleum industry is interested in nuclear energy both as a heat source and as a source of radiation energy. It has been one of the pioneers in the use of radioactive isotope tracers. Lubrication problems are being solved as they arise.

The brainpower and financial support being allotted to studies of radiation chemistry and physics by leading petroleum companies make it evident that this new source of energy is being fully explored. New and improved products and processes may be expected to result from such intensive research.

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About the Author

R. S. BARNETT *received a BS degree in chemistry from Southwestern Louisiana Institute in* 1929. *He then became a teaching fellow at New York university, where he obtained an MS in organic chemistry in* 1931. *He joined Texaco Inc. in* 1931 *at the Texaco Research Center, Beacon, N. Y., where he has been ever since. He is presently senior technologist, technical services managerial staff. Author or co-author of a number of articles on lubricating grease, fretting corrosion and chemical analysis, he is listed as co-inventor in seven patents on lubricants, and belongs to a number of ASTM committees and sections. A vice-chairman of the NLGI Technical Committee, he is a member of Phi Kappa Phi, Pi Kappa Delta, Pi Delta Epsilon, ACS, AIC(F) and RESA. Mr. Barnett is a previous contributor to the* NLGI SPOKESMAN.

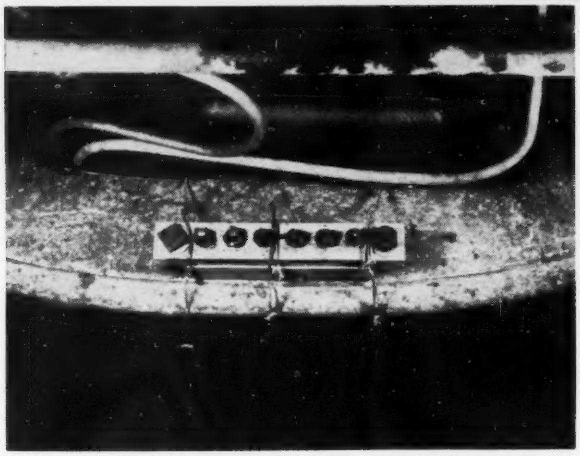


FIGURE 1—Fittings mounted under car.

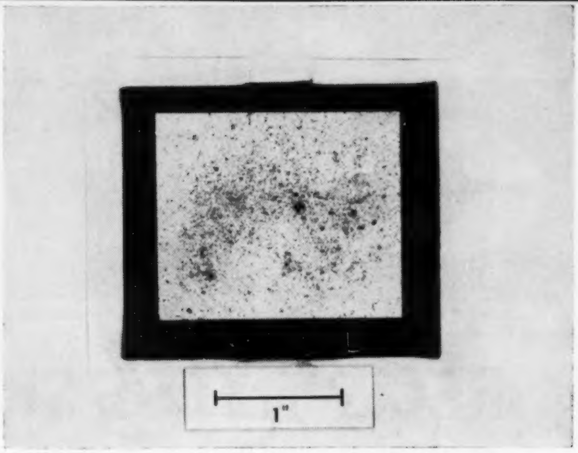


FIGURE 2—Dirt separated from dirty grease.

Deleterious Particles and Wear

By: L. C. Brunstrum and K. R. Bunting, American Oil Company

Two methods have been used to estimate the amount of extraneous dirt in lubricating greases. Federal Method No. 791-3005.1 determines the size and number of particles in a small grease sample under a microscope, but soft agglomerates of thickener are sometimes counted as dirt. In ASTM Method D 1404-56T, the grease is pressed between two transparent plastic plates at 200 psi; when the plates are rotated 30 degrees, "deleterious particles" are manifested by scratches. However, nothing has been published on the relation between these scratches and damage to bearings.

Some information on this relation was obtained with two greases in a study to show the need for wiping grease fittings before greasing them. Six dummy fittings, backed by individual receptacles, were wired under a car as shown in Figure 1. The fittings were then "greased" and the car was driven 1,000 miles to accumulate dirt. Every other fitting was wiped clean, and all were regreased with an amount of grease calculated to refill the receptacle.

Samples were obtained simply by removing plugs in the receptacles. Grease from wiped fittings appeared to be clean, whereas grease from the unwiped fittings showed traces of dirt. Figure 2 shows dirt washed out of one sample from an unwiped fitting.

Six replicate samples were tested by the ASTM method. In no case did grease from a wiped fitting scratch a plastic plate, as illustrated by Figure 3. All samples of dirty grease scratched the plates as shown in Figure 4.

Two samples of each dirty grease were wear-tested in the laboratory as described in the SPOKESMAN, Vol. XXIII, p. 399 (January, 1960). Comparing the results, in mg. of wear, with those on clean samples of both greases showed:

	Grease A		Grease B	
	Clean	Dirty	Clean	Dirty
	5	19	0.1	1
	8	27	1.0	2
	10	-	1.5	-
	21	-	2.5	-
Avg.	11	23	1.3	1.5

Statistical treatment of the data indicates no significant difference. Thus, dirt that scratches the plastic plates may not contribute to wear in bearings. ■

FIGURE 3—Plastic plates used with clean grease.

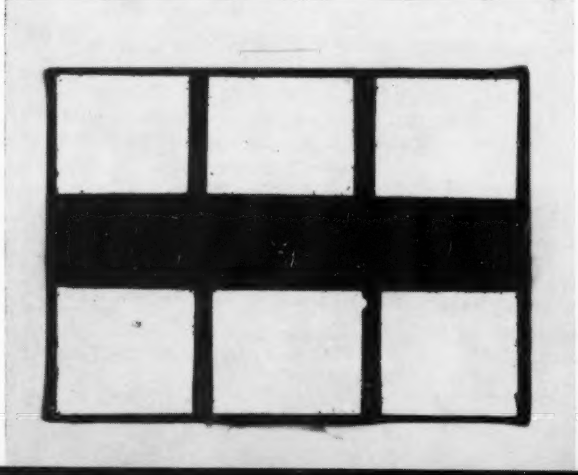
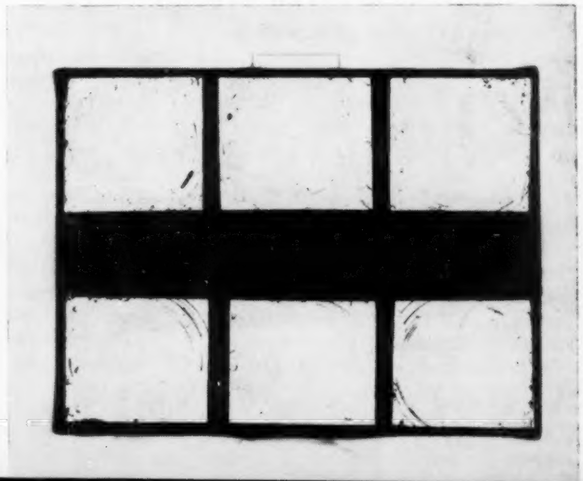


FIGURE 4—Plastic plates used with dirty grease.



CLIMAX MOLYBDENUM

Molysulfide® News Digest

CLIMAX MOLYBDENUM COMPANY, a division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N.Y.

RECENT TEST SHOWS MORE PROOF OF MoS_2's LOAD-CARRYING ABILITY

Grease Compounders Take Hard Look At Paste Type Concentrates

In a recent issue of NLGI SPOKESMAN, a prominent lubrication authority warns that in the future an increasing number of the newer machines will be greased "for life"—or for long lubrication intervals. He also says that as the industrial pace quickens and wages go up, it will be more economical to use more expensive grease and reduce lubrication frequency.

That's why grease compounders and blenders are looking into every possible way to maintain and increase their profit levels.

High on investigation priority lists are the paste type concentrates. These concentrates contain solid lubricants. Molysulfide concentrates can be applied by grease guns or by brushing, and will stand up at temperatures as low as -100 F. and peaks as high as +500 F.

Concentrate users include a fast spreading number of industries. Major manufacturers in the automotive industry use paste type Molysulfide concentrates for pre-assembly lubrication of splines, cams, etc.

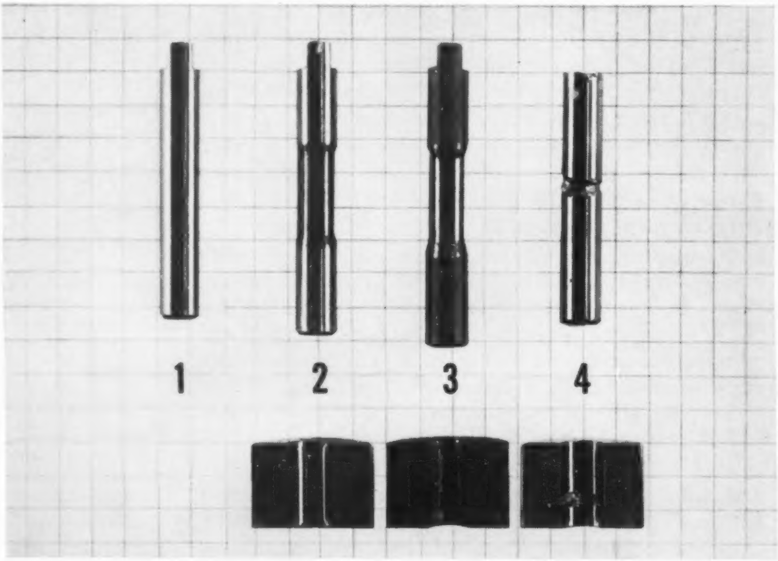
The aviation and missile industry is using an increasing amount to overcome low-temperature problems in servo-mechanisms, bearings and gears.

General industry is applying them, not only on metals exposed to continuous high temperatures, but also on plastic bearings, machine tool ways, press fittings and other moving parts where long lubricant life and high load carrying capacity is needed.

Much remains to be learned about the full potentialities of paste type concentrates but all signs indicate they are one of the answers to lubrication problems of the future.

When writing, refer to CL-110

From the German laboratory of Alpha Molykote Corporation comes new proof of Molysulfide's ability to resist galling and seizing at pressures beyond the yield point of most metals. Previous tests have shown that Molysulfide provides positive protection up to 475,000 psi. In this Alman Wieland test, similar to the Falex test, a ¼-inch pin actually extruded *without any surface damage* at pressures of 100,000 psi, while those using other lubricants were torn, galled or "frozen" to the point of breakage.



Photograph above shows mild steel test pins. No. 1: unused pin. No. 2 (lubricated with mineral oil and Molysulfide) and No. 3 (with Molysulfide bonded coating) were subjected to rotating pressures between bearing halves. Both were elongated and extruded without galling, seizing, or weight loss. No. 4 shows typical failure with conventional lubricant. Note that the key sheared off and pin and block were galled and seized.

Extensive surveys among a great many independent laboratories indicate that the extrusion phenomenon produced with Molysulfide has never been achieved with any other conventional lubricant.

This proven load carrying ability of Molysulfide is only one of the reasons why grease compounders and lubrication engineers are investigating and testing new uses for MoS_2.

Other reasons include its extremely low coefficient of friction; its wide temperature range from -300 F to 750 F; its tenacious adherence to metal surfaces and a resultant great resistance to "scrape-off" and "wash-off"; and, its high chemical stability combined with long-life characteristics.

The uses for solid lubricants are multiplying. And—by test—Molysulfide is the superior solid lubricant.

When writing, refer to CL-111

Literature and Patent Abstracts

Composition

Power Transmission Fluids

Power transmission fluids, such as automatic transmission fluids, which have little change in viscosity with change in temperature are described in a series of three U.S. Patents, namely 2,968,623 of which Darling is the inventor, 2,-968,624 by Vearch and Milberger, and 2,968,625 by Milberger and Darling. These patents are assigned to the Standard Oil Co., Ohio.

The preferred oil used in these fluids has a viscosity of 50 to 300 SUS at 100°F and 25 to 55 SUS at 210°F. The compounded fluid contains 1 to 3 per cent of an inorganic gelling agent, 1 to 60 per cent by weight of the gelling agent of an aliphatic amine having an aliphatic radical of from 8 to 20 carbon atoms, and 1 to 20 per cent by weight of the gelling agent of an imidazoline having an aliphatic radical of from 8 to 20 carbon atoms. That is, the first patent claims the use of all these additive ingredients whereas the other patents are restricted to the use of one only of the last two ingredients.

For example, a paraffin oil having a viscosity of 74.1 SUS at 100°F was mixed with 2.5 per cent of Santocel, 0.125 per cent each of Armeen 10-D and Amine O by recycling through a gear pump and then through a steel coil at 400°F and finally ejecting through a diesel injector nozzle set at 2500 to 3000 psi. The fluid then had a viscosity of 525 SUS at 100°F and a viscosity-temperature slope of zero. A mixture made from a solvent extracted oil having a viscosity of 150 SUS at 100°F with 1.5 per cent Santocel, 0.10 per cent Armeen 10-D, and 0.05 per cent Amine O and treated as above showed 6 per cent settling of the thickener after 42 days.

Siliceous Amino Compounds As Thickeners for Lubricating Greases

When a salt of a partial amide is reacted with a silicate salt, products which will form lubricating greases when dispersed in oils are formed. Such products are described by Ihde in U.S. Patent 2,-967,828, assigned to Nopco Chemical Co. The preferred partial amides are those obtained by reacting an alkylene polyamine with fatty acids having carbon chain lengths of eight to eighteen. Sodium, potassium or ammonium silicates can be used for the purpose.

For example, 250 grams of sodium silicate, consisting of a 40° Bé. solution of one mole of sodium oxide to 3.22 moles of silicon oxide, were dissolved in 1590 cc. of water and heated to 70 to 80° C. One hundred grams of a monoamide, prepared by reacting equimolar quantities of hydrogenated tallow fatty acids and tetraethylene pentamine, were heated to 80 to 90°C, where the mass was molten, and dispersed in 957 cc. of water which had been heated to 70 to 80°C. To this dispersion, 42.8 grams of glacial acetic acid were added to give a clear solution of the acetate salt of the monoamide.

The latter solution was then added slowly to the sodium silicate solution with stirring while both solutions were maintained at 70 to 80°C. A yellowish, creamy dispersion of the siliceous amino compound formed almost immediately but the temperature was maintained for an hour while stirring. After filtering, the solids were washed four times using a liter of water heated to 45 to 40°C in each case. Finally the mass was dried at 150 to 155°F before grinding.

Twenty-three per cent of a similar thickener was dispersed in a 300

viscosity (SUS at 100°F) oil by stirring at room temperature. After passing the mixture through a mill adjusted to 0.015 inch clearance, a lubricating grease with a worked penetration of 252 resulted. This had a dropping point above 500°F, showed no oil separation at 150 to 220°F, did not disintegrate in the presence of water, and inhibited the corrosion of ferrous metals. This lubricant was said to be unique in that the unworked penetration was lower at an elevated temperature than at about room temperature: thus, 275 at 90°C and 316 at 30°C.

Improving the Yield of Sodium Base Lubricating Greases

Roach, Lyons and Dilworth in U.S. Patent 2,969,325, assigned to Texaco Inc., claim that the addition of 0.5 to 3 per cent by weight of the estolide of 12-hydroxy stearic acid to sodium base lubricating greases stiffens the product so that less soap is necessary for a given consistency. While the estolide can be included in the ingredients initially used in conventional manufacture of sodium base greases, it is also possible to add this material to a finished lubricant after which the mass is heated to above 300°F and then cooled.

The value of estolides is shown in the formulations in Table 1.

Use of this estolide also permits the production of lubricating greases from sodium soaps of caproate, caprylate or caprate acids. Likewise, the action of improving yields also takes place in sodium base lubricating greases containing organic thickeners, such as indigo.

However, the use of estolides is specific to sodium base products. In lithium base lubricating greases, such additions result in softening rather than stiffening.

Table 1

COMPOSITIONS, PER CENT

Sodium laurate	23.8	13.6	18.7	19.8
Excess NaO^{H}	0.2	0.1	0.2	0.1
Na soap of estolide of 12-hydroxy stearic acid	—	0.8	1.2	1.1
Distillate oil	13.2	7.5	10.2	10.7
Residual oil	58.8	74.0	66.3	64.5
Diphenyl-p-phenylenediamine	1.0	1.0	0.9	1.0
Tricresyl phosphate	3.0	3.0	2.5	2.8
Worked penetration at 77°F	288	297	296	279

Radiation Resistant Lubricating Greases

In British Patent 853,751, Esso Research and Engineering Co., Morris and Agius describe lubricating greases which are resistant to the

effects of radiation and hot carbon dioxide gas. These consist of mineral lubricating oils, containing five to 50 per cent, based on the total composition, of certain hydrocarbon polymers, and eighteen to 23 per cent of acetylene black as a thickener. The preferred polymers, which should have molecular weights of 500 to 2000, are polyisobutylene, polyethylene, or butyl rubber.

For example, a lubricating grease was made from 20 per cent acetylene black, 47.4 per cent mineral oil phenol extract, 31.6 per cent polyisobutylene of 1000 molecular weight, and 1 per cent of phenyl beta naphthylamine. The polymer and the antioxidant were dissolved in the oil which was heated to 120°C. This oil mixture was then added slowly to the acetylene black with constant stirring which was continued for one hour after the complete addition of the oil.

This formed a lubricating grease which had a penetration of 294. After subjecting the product to a radiation dosage of 1×10^8 Rads, the penetration was 305 and after a dosage of 3×10^8 Rads the penetration had changed to 310.

Car Wheel Lubricant In Solid Stick Form

A stick which, when held against car wheel flanges, provides lubrication is described by May in U.S. Patent 2,970,109. This stick is formed by first mixing 80 to 95 per cent of graphite and $6\frac{2}{3}$ to $2\frac{1}{2}$ per cent of sulfur and then adding $13\frac{1}{3}$ to $2\frac{1}{2}$ per cent of a phenol formaldehyde binder admixed with an ammonia catalyst. The ratio of the phenol to the formaldehyde in the binder is 90 to 95 per cent of the former to 10 to 5 per cent of the latter. This mixture forms a dough which is molded under a pressure of at least 2000 pounds and at a temperature of about 250°F.

Alkylene Higher Fatty Acid Diamides As Oil Thickeners

Compositions, having thixotropic properties, result if oils are thickened with 0.25 to 30 per cent by

weight of N,N'-methylene bis-stearamide (Armowax) or N-N'-ethylene bis-stearamide (Acrawax C). Such products are described by Shoemaker in U.S. Patent 2,971,914, assigned to Research Products Corp.

Lubricating greases are prepared by melting the wax mixed with the oil to a point above the cloud point and then shock chilling by pouring on a flat metal plate or a water-cooled cylinder. The rate of cooling influences both the texture and consistency of the finished product. With a particular mixture a cooling rate of 189 degrees C per minute gave a very dull, somewhat coarse and grainy material with slight oil separation. When the cooling rate was changed to 1148 degrees C per minute the product was smooth, glossy, more translucent than the above sample and the oil was firmly held.

Using a mixture of 8 per cent Acrawax C and 92 per cent of an oil having a viscosity of 3455 SUS at 100°F, and shock-chilling, a heavy lubricating grease resulted. Using five parts of Acrawax C, three parts of glyceryl monostearate, and 92 parts of a white oil having a viscosity of 350 SUS at 100°F, a stable thixotropic lubricating grease resulted which was resistant to moisture and had rust-inhibiting properties. While characteristics are not given for either of these products, the latter is stated to be suitable for general household use and can be dispensed from a collapsible tube.

Characteristics

Relaxation Phenomena In Lubrication
E. O. Forster, *Lubrication Engineering* 16, pp 523-28 (1960).

Lubricants possess both elastic and viscous properties, that is, when stressed, it takes a finite time before they exhibit viscous flow. The characteristic time that is required for the onset of flow is called the relaxation time and the transition from elastic to viscous response is referred to as relaxation phenomenon.

Forster finds that lubricating greases appear to behave elastically in time intervals of 0.1 seconds or longer. Further, we quote: "If the time during which the lubricant is subjected to rapid stressing is of the same order of magnitude as the relaxation time, then the lubricant will behave elastically rather than viscously. Under these conditions, the lubricant will be present as an elastic film which can carry heavier loads than a viscous film and at the same time can prevent contact between the bearing surfaces and thus reduce or eliminate wear."

Unmodified lubricating oils have the shortest relaxation time and lubricating greases the longest relaxation time of the products considered with polymer-modified oils intermediate.

Additives

Stabilizing Lubricating Greases

Condensation products of beta-lactones and polyamines are said to stabilize lubricating greases against deterioration. Such claims are made by Thompson in U.S. Patent 2,968,-

618 assigned to Universal Oil Products Co., but no examples are given to verify such a suggestion.

Application

Lubrication In Space
M. M. Freundlich and C. H. Hannan, *Lubrication Engineering* 17, pp 72-77 (1961)

With the aim of being able to operate small motors in space for periods of over a year, the authors screened 40 oils and 25 lubricating greases. First, the lubricants with highest evaporation rates were eliminated. For this purpose samples in glass jars were subjected to a vacuum of 10^{-7} mmHg and 110°C for two to five days after which the loss was determined by weighing. Finally, the products with the lowest evaporation rate were run in bearings of 400 c.p.s. hysteresis motors all in a chamber with a vacuum of 2×10^{-5} mmHg. Tests were run for 1000 hours unless failure occurred.

Six lubricating greases were subjected to the last test with results as follows:

A silicone fluid thickened with a lithium soap operated 900 hours and the failure was due to electrical trouble.

Another silicone fluid thickened with indanthrene ran 1000 hours.

A complex ester lubricating grease in which the type of thickener was not given ran 1000 hours.

A mineral oil thickened with a clay base and also containing 3 per cent of molybdenum disulfide ran only 400 hours due to mechanical trouble.

The Literature and Patent Abstracts column is written for NLGI by C. J. Boner, chief research chemist for Battenfeld Grease and Oil of Kansas City, Missouri.

In the case of an ester having a non-melting thickener and a silicone fluid thickened with lithium soap, the runs were concluded at 230 and 220 hours due to failure of the lubricants.

Lubrication of Automotive Worm-Gears
***Scientific Lubrication* 13, No. 1 January 1961 p. 30.**

A summary is given of a paper presented by J. Whittle before the Automobile Division of The Institute of Mechanical Engineers in London on January 10th.

Due to pitting and wear of bronze worm-gears and also thickening of conventional mineral oils, the number of new vehicles fitted with worm-gear axles in Great Britain is decreasing. Therefore, tests have been made employing a synthetic oil. This consists of an oxidation inhibited poly-alkylene oxide derivative having a kinematic viscosity at 210°F of about 22 cs. and a V.I. of 140.

On a dynamometer test at full load for 400 hours, this synthetic showed no pitting and only slight wear of the worm-wheel. Under the same conditions, an SAE 140 mineral oil gives severe wear and pitting of the wheel. Using a modified friction disc machine in which the fluid was heated to 150°C and run for 500 hours, the synthetic oil decreased in viscosity about 10 cs. while an inhibited SAE 140 mineral oil became 20 cs. heavier in only 120 hours.

Food for Thought

The following quotation accompanies an article by C. W. Cassells and E. J. Kamp of Link-Belt, in the March 1961 *Chemical Processing*, p. 115.

It seems that our organization should subscribe to and work towards the suggestion in the last paragraph.

"Your grease monkeys are high-priced luxuries.

"The oiler or grease monkey usually has one of the lowest-paid jobs on the labor force. This policy is a high-priced luxury that industry can no longer afford. Modern machinery has outgrown the grease monkey.

"It has been our observation that greasers usually fall into one of the following categories:

1. They are older persons given the assignment awaiting retirement.
2. They are not mechanically inclined.
3. Usually they do not look beyond the assigned task of greasing or oiling.
4. Although frequently asked to make written reports, most greasers are incapable of that task.

"We believe that the greaser should be upgraded. Greasing and oiling machinery and equipment should be the responsibility of a first-class mechanic. When he is performing the rather simple job of oiling and greasing, he is in the unique position of being able to recognize impending equipment failure. This man should be a preventive-maintenance detective, who is capable of interpreting unusual sounds, vibrations, smells and other such symptoms."

though numerous tests were made, the dirty grease did not result in more wear than the normal range of the clean samples. Thus, some dirt which will scratch a plastic plate will not be injurious to some bearings.

ASTM D 1403 Micro Worker

As a result of correspondence with a German firm, this method was carefully scrutinized. It was found that the cup dimensions are $\frac{3}{4}$" x $\frac{7}{16}$" with no tolerance shown. Thus, equipment makers might apply an automatic $\pm\frac{1}{16}$" tolerance which is excessive. It was decided to make an editorial change to decimal dimensions, thus providing a smaller automatic tolerance (which may also be shown).

ASTM D 972 Evaporation

The ASTM and Government methods were compared. Although there are differences in temperature and time, there appears to be no reason to modify the ASTM method.

Respectfully submitted,
L. C. Brunstrum
Chairman, Section II

Report of Subsection G-II-2 Dropping Point of Greases February 6, 1961

Subsection 2 – Section II on "Dropping Point of Lubricating Greases" met on February 6, with 24 members and interested parties in attendance. History and reasons pertinent to the reactivation of Subsection 2 were reviewed.

Work of the Subsection is separated into two phases: (a) redetermination of the precision of ASTM D 566 and (b) development of a dropping point method and equipment suitable for operation at temperatures above 500°F.

Since the June meeting, members of the Subsection ran dropping points on ten cooperative greases and reported results of tests.

Two of the samples, GII-113 and GII-115, were greases of conventional types with dropping points of about 350°F and 400°F, respectively. Results of tests by ASTM D 566 on these greases in general fell outside the limits for precision specified by ASTM D 566. It was felt that lack of precision could be attributed, partially at least, to variations in rate of heating.

The other cooperative greases contained thickening agents having melting points well above 500°F. Methods and equipment used for the determination of dropping points for these samples were optional with the exception that the grease cup, test tube, etc., specified by ASTM D 566 were adhered to. Precision of results on these samples was very poor but not unexpected in view of wide variations in heat-

ing rates.

A second series of cooperative tests involving more closely controlled rates of heating has been scheduled and will be completed prior to the June meeting.

Respectfully submitted,
P. R. McCarthy
Chairman, Subsection G-II-2

Report of Subsection G-II-12 Roll Stability Tester February 6, 1961

The meeting of Subsection 12 of G-II on the Roll Stability Tester was held on February 6, 1961. Twenty-six members and guests were present.

The result of a letter ballot circulated to the Subsection members on September 26, 1960, was reported. This ballot showed 14 "ayes," and 6 "nays." The ballot referred to the acceptance of a proposed method of test using the Roll Stability Tester. Since the reason for "no" votes in most cases was accompanied by suggestions for editorial changes, the proposed procedure was reviewed in committee and the changes made. By voice vote, the chairman was empowered to rewrite the procedure for resubmittal to the members of Technical Committee G by letter ballot.

Respectfully submitted,
J. S. Aarons, Chairman,
Subsection G-II-12

Report of Section IV Lubricating Grease Research Techniques

Section IV held a meeting on January 20, 1961, in San Francisco, California, with seven members and two guests present. This was the second meeting under our present assignment, which is to investigate the factors involved and to recommend a method of test for determining the temperature at which high temperature greases change from a semisolid to a liquid. Initially, each laboratory is acting independently in exploring any promising method, for which they are equipped.

Two laboratories reported observations made using apparatus similar to that used for the determination

of melting points of crystalline solids. One consists essentially of an aluminum bar, 1-inch square, 18 inches long, which is heated at one end by means of a flame. It was assumed that the temperature along the bar was proportional to the distance from two thermometers sunk into the bar. Small portions of grease were touched to the bar at various calibrated points. The temperature of the spot where the grease just melts was calculated as being the melting point of the grease. With some greases, repeatability was good; but with others, no well-defined softening point could be detected. The second apparatus of this type consists of an electrically heated rod. Both instruments can be calibrated with crystals of known melting points. These two instruments provide a simple and rapid means of determining the behavior of greases during heating and melting. Further studies will be made of the temperature/consistency characteristics of various greases.

Another laboratory has been conducting tests with an instrument known as the Bendix Ultra Viscoson. This involves the use of a long, thin probe which vibrates at an ultrasonic rate. The probe is dampened by the test fluid, and the amount of dampening indicates the fluid viscosity. When used with standard fluids, the results proved quite accurate. The results obtained to date with grease have not been very satisfactory because of variation in the temperatue of the grease during heating. However, a method of this type has possibilities; and the use of a smaller sample and a smaller probe may make an improvement.

Two laboratories have been conducting tests using Brookfield Viscometers. As the first need in a test of this type is uniformity of heat transfer, several modifications of the apparatus were made to improve heat transfer when testing grease:

1. The size of the sample and the sample container was reduced.
2. The sample container was coupled to a small motor and rotated, 5 rpm, countercurrent to the rotation of the Brookfield spindle.
3. The "U"-shaped guards were replaced with stainless steel wire guards to agitate the grease adjacent to the walls of the container.
4. A Brookfield-motorized Helipath Stand was used to alternately lower and raise a special bar-type spindle to prevent channeling in the grease.

Test results obtained to date with lithium and soda soap greases show that a sharp drop in apparent viscosity occurs at close to the ASTM dropping point temperature. A complex soda soap grease showed variations in apparent viscosity which apparently coincide with phase changes characteristic of this type of grease. Nonmelting greases showed some decrease in apparent viscosity, but remained above 10,000 centipoises at temperatures as high as 700°F. As these results appear promising, further studies will be made to improve the test and to determine the repeatability.

Respectfully submitted,
Harold A. Woods
Chairman, Section IV

The following, submitted by W. A. Magie, Magie Bros. Oil Co., chairman of the API-NLGI Joint Container Subcommittee, is a report of the Petroleum Packaging Committee meeting held recently in San Francisco, Calif.

L. C. Cannella of Continental Can told of developments in the use of double reduced tin plate (about half the thickness of conventionally rolled tin plate) in making oil cans. Present recommendation is 60 lb. bodies and 65 lb. ends. The double reduced plate is high temper, directional in grain, stronger than conventional plate of the same gauge, and has a dull finish. Dent tolerance is about halfway between aluminum and regular steel.

Large Containers Sub-Committee

Recent checks indicate standard 55 gallon drum dimensions vary substantially in practice, enough to interfere with pelletizing and stocking. Circumferential tapes are available for easy and accurate direct reading of diameter of drums.

Tapered 5 gallon L.C. pails — Combination straight and tapered side pails of varying designs are being developed by several manufacturers. There may be disadvan-

tages in shipping the filled pails.

Bulk handling — Interest is being shown in the new Bulk Packaging and Containerization Institute. Shell continues use of the rubber Sealdrum for grease. Steel bulk bins are in trial usage.

Within the last 30 days, the I.C.C. reached a compromise on the controversial issue of who should be allowed to use collapsible shipping containers. Its decision: only tank truckers can carry premounted rubber bags and containers, while general commodity truck operators may use collapsible containers only if they are filled off the truck and then loaded. Most traffic men had hopes they might win lower freight rates if public commodity truckers were allowed to use collapsible tanks and bins, since these carriers can generally get revenue producing return hauls more easily than can highly specialized tank truck operators.

Traffic

Final approval for shipment of gap-flap cartons will be effective in May.

Approval has been received for truck shipments of gear lubricants heavier than 900 SUS at 100° in 24 gauge 120 lb. drums; rail shipments of this drum are approved for grease only. Continued authorization is expected for motor truck shipments of 20/18 gauge 55 gallon drums. Proposal to reduce 24/1 quart cartons to 175 lb. test was disapproved. Likewise, proposal for establishing a uniform shipping weight for new 55's was rejected.

Government Advisory Sub-Committee

Mil-std-290 has been revised to describe three degrees of packaging. Details are summarized of the three levels applied to various types of containers.

Small Containers Sub-Committee

Some nine companies have made test shipments on the light-weight steel cans. The resulting denting of the cans is not satisfactory to some of the companies. The sub-committee will investigate use of light-weight four or five quart cans. Some three or four companies are switching from five quart to four quart cans (where lighter steel should be more satisfactory.)

New Company Formed

Formation of a new company for overseas management and manufacture has been announced by Gordon D. Zuck, president, who said the new company will be known as Vulcan International, S.A., and will have its headquarters in Panama City, Republic of Panama. Representatives' offices will be located in Birmingham, Ala., River Forest, Ill., and in New York City.

Zuck said the new company will operate steel pail and drum manufacturing plants at selected locations in foreign countries and will utilize the many years of experience in this business, represented by the offices and staff, to manage operations abroad. He is president and director of Vulcan-Associated Container Companies, Inc. with headquarters in Birmingham.

Vern I. McCarthy, Jr., will serve as treasurer. He is also president of Vulcan Containers, Inc., of Bellwood, Ill., and an officer of some of the other Vulcan Container domestic companies.

Appointed Canadian Sales Agent for Foote

The Caledonia Co. Ltd., of Toronto, Canada, has been appointed exclusive sales agent in Canada for lithium chemicals produced by Foote Mineral Co. Foote officials said that an agreement has been signed, and is now in effect, under which certain lithium products will be stored in Caledonia's Toronto warehouse for distribution to Canadian users. The arrangement is expected to speed shipments and provide better service for grease producers.

Service Aids

Send Orders to: National Lubricating Grease Institute, 4638 Nichols Pkwy., Kansas City 12, Mo.

FOIL SEALS OF NLGI'S NEW PROMOTION CHARACTER—Aluminum foil stickers, measuring one by one-and-a-half inches, show NLGI's

little man in full color . . . add a distinctive touch to correspondence, advertising, etc. Box of one thousand, $7.50, postage paid.

BALL JOINT BOOKLET — "Recommended Practices for Lubricating Passenger Car Ball Joint Front Suspensions." The latest aid in application, created by experts in the field and designed for use in the station. Twelve pages, easy to read, with large illustrations throughout. Twenty-five cents a copy with quantity discounts—company imprint arranged.

WHEEL BEARING MANUAL — "Recommended Practices for Lubricating Automotive Front Wheel Bearings." More than 170,000 copies of this booklet have been distributed throughout the world. Now in its sixth printing. Sixteen pages, with more than 40 illustrations. Twenty-five cents a copy, with quantity discounts — company imprint arranged.

VOLUME XXIV—Bound Volume of the NLGI SPOKESMAN from April, 1960 through March, 1961. Contains 38 articles and features on every phase of the lubricating grease and fluid gear lubricants industries . . . $7.50 (NLGI member price) and $10.50 (non-member) plus postage.

VOLUME XXIII—Bound Volume of the NLGI SPOKESMAN from April, 1959 through March, 1960. Contains 36 features on every phase of the lubricating grease and fluid gear lubricants industries . . . $7.50 (NLGI member price) and $10.50 (non-member) plus postage.

VOLUME XXII—Bound Volume of the NLGI SPOKESMAN from April, 1958, through March, 1959. Contains 31 articles and features dealing with lubricating greases and gear lubricants . . . $7.50 (NLGI member price) and $10.50 (non-member) plus postage.

BONER'S BOOK—Manufacture and Application of Lubricating Greases, by C. J. Boner. This giant, 982-page book with 23 chapters dealing with every phase of lubricating greases is a must for everyone who uses, manufactures or sells grease lubricants. A great deal of practical value. $18.50, prepaid.

NLGI MOVIE — "Grease, the Magic Film," a 16-mm sound movie in color running about 25 minutes, now released. First print $300, second and subsequent orders $200 each (non-members add $100 to each price bracket).

CATO MOVIE — "Lessons to be Learned from the Cato Grease Plant Fire." A 16-mm sound movie, 26 minutes, depicting how to avoid a fire in a lubricating grease manufacturing plant with step-by-step procedures. May be reserved without charge. A gift of Cato Oil & Grease.

LINCOLN MOVIE — "You—the Jury," a 16-mm sound movie in color, 18 minutes, telling the application story in the lube bay. May be reserved without charge from NLGI. A gift of Lincoln Engineering Co.

NLGI GLOSSARY—A four-page booklet containing definitions of terms relating to the lubricating grease industry. Usable by marketing as well as technical people. Fifteen cents per copy (NLGI member price) and twenty-five cents (non-member).

REPRINTS — From the NLGI SPOKESMAN are available at low cost. Page forms are left standing for three months, company imprint or advertising arranged.

People in the Industry

Sklarz Appointed by ADM's Chemical Group

Appointment of Everett Sklarz, New York, as eastern regional sales manager for Archer-Daniels-Midland Co.'s chemical group was announced by George K. Nelson, chemical group marketing manager.

Sklarz will be in charge of all administrative and sales matters for all ADM chemical group products in the area covered by the company's New York regional office.

Eastern regional manager for ADM resins for the past three years, Sklarz joined the company in 1948 as a technical sales representative. A chemical engineering graduate of Purdue university, he previously was associated with several protective coatings manufacturers.

Cubicciotti Receives Certificate of Appreciation from API

Rudolph Cubicciotti, vice president of Witco Chemical company, Inc., was presented with a certificate of appreciation by the American Petroleum Institute at its mid-year-meeting banquet on May 18.

The presentation was in recognition of Mr. Cubicciotti's contributions to API's Marketing division as a former chairman of the Lubricating committee and as chairman of its Motor Oil Study panel.

In addition to his activities for the API, Mr. Cubicciotti is also a director of the National Lubricating Grease Institute, of which he was president in 1958.

He has been administrative vice president of Witco since November 1960. He was previously vice president of Sonneborn Chemical and Refining corporation, a Witco subsidiary. Before that, he was product sales manager of Union Oil company of California. He is a graduate of the University of California with a B. S. in Chemical Engineering.

Active in the affairs of several yachting and boating organizations, Mr. Cubicciotti is presently vice commodore of the Eastern Cruiser association.

Rheem Promotes E. M. Bartlett, Jr.

E. M. Bartlett, Jr., has been promoted to vice president-marketing, western region, for the container division of Rheem Manufacturing company, A. Lightfoot Walker, president, announced in New York Mr. Bartlett will be responsible for all marketing activities in the eleven western states on all steel and fiber shipping containers. He will continue to maintain his office at the Richmond, Calif. plant.

Container division headquarters are at Linden, N. J. Western region container plants are at Richmond and South Gate, Calif. and Tacoma, Wash.

Henry W. Armstrong Retires from Dixon

The Joseph Dixon Crucible Co., Jersey City, N. J., announced the retirement of its vice president in charge of finance, Henry W. Armstrong. Mr. Armstrong will continue to serve Dixon as a board member and as a member of its executive committee.

Mr. Armstrong joined the Dixon organization 58 years ago, starting as an office boy. After terms of service in the company's sales and export departments he ascended to executive rank, first as credit manager, and successively was assistant treasurer, treasurer, secretary-treasurer and then vice president.

Changes in Sales Staff Announced by Emery

Joseph E. Quinty, Chicago sales representative of Emery Industries, Inc., has been appointed assistant sales manager of Emery's organic chemical division and will move to the firm's home office in Cincinnati, Ohio.

Mr. Quinty, who has been head of Emery's Chicago office for the past four years, will assist sales manager James W. Ritz in sales of the firm's organic acids, plasticizers and jet engine lube bases.

A past director of the Midwest Chemical Salesman's association, Mr. Quinty is a member of the American Chemical Society, the

Society of Plastics Engineers, the American Society of Lubrication Engineers, the Chicago Rubber Group and the Chicago Drug and Chemical Association.

Sales representatives Leslie R. Graham and Robert H. Strawbridge have been assigned to Emery's Chicago office from the Cincinnati headquarters. This fills the vacancy left by Mr. Quinty and also expands the Chicago staff for better coverage and service of accounts. Both are also graduates of Purdue university, Graham with a Chemical Engineering degree, and Strawbridge with a B.S. in Chemistry.

Sales representative Thomas A. Williams has been assigned to Emery's Philadelphia territory to replace J. P. Clancy. Mr. Williams has a B.S. in Chemical Engineering from Princeton university and a M.B.A. in business from Harvard university. He has been participating in Emery's sales training program for the past year. He is a member of the American Chemical Society.

Lindsay C. Taliaferro, Jr., has been assigned to Emery's New Jersey sales territory. He will replace R. S. Haley, who has been promoted to sales manager of Emery's Vopcolene division on the West Coast. Mr. Taliaferro has been in chemical sales work for the past three years, after obtaining a B.S. in Chemical Engineering from the University of Pennsylvania.

Offers Dry Film, Bonded Lubricant for Service At Extreme Temperatures

Molykote X-15, an inorganic-bonded, dry film lubricant with a useful temperature range of from −300 to +1200°F, is now being produced by the Alpha-Molykote Corp. under a licensing agreement with its inventors. The extreme-environment lubricant was developed by scientists at one of the nation's leading research centers after years of experimentation and testing.

In addition to its wide temperature range, Molykote X-15 is insensitive to liquid oxygen; has proven to be unaffected by up to 5×10^8 roentgen gamma radiation; retains its lubricating properties under vacuums up to 10^{-9}mm of Hg; and is easy to apply in either shop or field.

The lubricant has proven effective under a wide range of severe environmental conditions. Specific examples include: 50 hours operation on a thrust ball bearing at 840°F; on a ball bearing immersed in liquid oxygen for 1 hour at 3600 rpm followed by 350°F operation at 10,000 rpm; on a part operated at 10^{-9}mm Hg and 400°F and 10^{-3}mm Hg at 1,000°F; and on a ball bearing operating at 3,500 rpm at room temperature for 1,000 hours. Starting torque of the new lubricant at −100°F is 12.5 in. lb compared to 126 in. lb for conventional −100°F grease.

Molykote X-15 can be applied by brushing or spraying. It air dries to a tough, resilient coating in one hour at room temperature. Wear life can be increased by allowing the coating to air dry for 30 minutes and then baking at 180°F for one hour. Surfaces should be cleaned before application. Removal of all organic residues is essential for oxygen service. No other surface pretreatment is necessary, but sandblasting or liquid honing will increase the wear life of the coating.

Because it is used in liquid oxygen service, and with other active reagents, Molykote X-15 is formulated and packaged with strict laboratory care. Shelf life is six months minimum and each package is stamped with the expiration date.

Additional information may be obtained without cost from the Alpha-Molykote corporation, 65 Harvard Ave., Stamford, Conn.

Heinis, Paquette to Top Posts of Rheem's Home Products Group

V. J. Heinis has been appointed president and E. F. Paquette executive vice-president of Rheem Manufacturing Co.'s home products group, A. Lightfoot Walker, Rheem president, announced. Mr. Heinis had been vice-president and general manager, home products group, and Mr. Paquette had been vice-president and general manager of the Rheem container division, Linden, N. J.

W. S. Goodfellow, who had been vice-president-marketing, container division, has been promoted to vice-president and general manager of the division; A. W. Nides, who had been container division central region sales manager, Chicago, has been promoted to vice-president-marketing for the division, the announcement said.

The container division makes steel and fiber shipping containers and food processing and handling equipment. Plants are at Chicago; New Orleans; Linden, N. J.; Freeport and Houston, Texas; Richmond and South Gate, Calif., and Tacoma, Wash.

YELLOW CAB INCREASES THE TIME BETWEEN LUBRICATIONS WITH CATO'S AMAZING NEW JT-6 GREASE!

Guy Fuller Jr., manager of the Oklahoma City Yellow Cab Company, says: "JT-6 is a far better grease for chassis lubrication than any we've ever used before – so much better that we're already running our cabs much longer between lubrications, and it appears that results will be even better."

JT-6 incorporates a new raw material that has never before been used in the commercial production of a lubricating grease. It has an unequalled ability to stay put on the moving surface where the lubricating job must be done and done safely—especially in ball joints and on fifth wheels. We believe there's no grease like it and that once you've tried it, you'll never accept a substitute. Write, wire or call for complete information.

CATO OIL AND GREASE COMPANY
Oklahoma City, Oklahoma

ENGINEERED LUBRICATION